ANNUAL REPORT

OF THE

VIRGINIA POLYTECHNIC INSTITUTE

Agricultural Experiment Station

1913, 1914

CONTENTS

THE more popular and immediately applicable results of the work of this Experiment Station are presented in Bulletins and Circulars, which are for general distribution. This Report contains, aside from a brief statement of the work in progress, the Meteorological Reports for 1913 and 1914, the following special articles, mostly technical, which are not published elsewhere:

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

1913, 1914

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

LYNCHBURG, VA.
BROWN-MORRISON CO., INC., PRINTERS
1915

LETTER OF TRANSMITTAL.

To His Excellency, Governor Henry C. Stuart:

SIR: In accordance with the Federal laws, approved March 2, 1887, and March 20, 1906, I transmit for your consideration the report of the Virginia Agricultural Experiment Station for the years 1912-13 and 1913-14.

Respectfully submitted,

W. J. SCHOENE, *Acting Director.*

April 1, 1915.

ORGANIZATION

OF THE

Virginia Agricultural Experiment Station

BOARD OF CONTROL

The Executive Committee of the Board of Visitors of the Virginia Polytechnic Institute.

JOHN THOMPSON BROWN, Chairman	Brierfield, Bedford County
J. B. WATKINS	Midlothian, Chesterfield County
J. A. TURNER	Hollins, Roanoke County
W. C. SHACKLEFORD	Proffit, Albemarle County
W. D. MOUNT	Saltville, Smyth County
J. D. EGGLESTON, ex officio	Blacksburg, Montgomery County

STATION STAFF

J. D. EGGLESTON, A. M.	President
W. J. SCHOENE, M. S.	Entomologist and Acting Director
H. L. PRICE, M. S.	Horticulturist
W. B. ELLETT, Ph. D.	Chemist
H. S. REED, Ph. D.	Plant Pathologist and Bacteriologist
T. B. HUTCHESON, M. S.	Agronomist
R. E. HUNT, B. S.	Associate Animal Husbandman
A. W. DRINKARD, JR., Ph. D.	Associate Horticulturist
E. R. HODGSON, M. S.	Associate Agronomist
H. H. HILL, M. S.	Associate Chemist
G. C. STARCHER, B. Agr.	Assistant Horticulturist
C. H. CRABILL, M. S.	Assistant Plant Pathologist
W. G. HARRIS, M. S.	Assistant Chemist
BRUCE WILLIAMS, M. S.	Assistant Bacteriologist
M. T. SMULYAN, Ph. D.	Assistant Entomologist
C. I. WADE	Treasurer
J. B. FOGLEMAN	Executive Clerk

COUNTY EXPERIMENT STATIONS

E. R. HODGSON, M. S. .... Supervisor County Experiment Stations

W. W. GREEN, Supervisor Tobacco Investigations, and Superintendent Bowling Green, Axton, and Louisa Stations.

B. G. ANDERSON, B. S.	Superintendent Appomattox Station
R. P. COCKE	Superintendent Williamsburg Station
J. M. TRIMBLE, B. S.	Superintendent Staunton Station
J. C. HART, B. S.	Superintendent Chatham Station
A. N. HODGSON, B. S.	Superintendent Martinsville Station
D. D. DIGGES, B. S.	Superintendent Charlotte Station
E. T. BATTEN, B. S.	Superintendent Holland Station

Bulletins and reports are mailed free to all residents of the State who apply for them.

CONTENTS

REPORTS

SPECIAL ARTICLES

Virginia Agricultural Experiment Station

REPORT OF DIRECTOR.

President J. D. Eggleston,
Virginia Polytechnic Institute.

SIR: I submit herewith a report of the work of the Virginia Agricultural Experiment Station, for the fiscal years 1912-13 and 1913-14.

The Staff.

There are now twenty-two men on the staff, of whom seven divide their time between College teaching and investigation, and fifteen devote all their time to investigation.

During the past few years there has been a great demand for capable men in all phases of agricultural work. This demand for men makes it hard for the Experiment Station to secure that continuity of effort which is productive of the best results, and is an obstacle that must be met by all agricultural institutions throughout the country. The Virginia Agricultural Experiment Station has been fortunate, for, although several changes have occurred that have necessitated a rearrangement of the work, all of the important investigations have been continued and some new projects initiated. The changes in staff and the readjustments necessary are briefly as follows:

During the autumn of 1913, Dr. N. S. Mayo, Animal Husbandman, resigned to take up veterinary advisory work in Chicago, and later to edit the organ of the American Veterinary Association, of which he is secretary.

Dr. E. B. Fred resigned to take charge of the work in Soil Bacteriology at the University of Wisconsin. During the two years following the time he returned from Germany, Doctor Fred did a large amount of work and won the recognition of bacteriologists elsewhere—hence, he was called to a larger field. With his departure, the Department of Bacteriology and the Department of Plant Pathology were merged, with Dr. H. S. Reed in charge. Mr. Bruce Williams was appointed Assistant Bacteriologist to complete the projects left by Doctor Fred.

At the close of the two-year period embraced by this report, Doctor Fletcher withdrew from the Directorship of the Experiment Station, to engage in editorial work and to take charge of his fruit farm at Fishersville. During the six years Doctor Fletcher was connected with the institution he not only built up an effective organization for research, but his work was highly

useful within the State and has attracted general attention throughout the country.

Professor W. J. Schoene, Entomologist to the Station, was appointed Acting Director.

Publications.

The policy as outlined in the last Annual Report of publishing the more technical investigations of the Experiment Station in the Report instead of in bulletins, has been continued. The Report is sent only to investigators and to those who request it. The bulletins containing the more popular results of the work of the Station are sent to the full mailing list. At present, the Station mailing list contains about thirteen thousand names, of whom nine thousand are residents of Virginia, and four thousand are residents of other States, including investigators, workers in the United States Department of Agriculture, Scientific Associations, etc.

Aside from the technical papers in the Report, the following publications have been issued since the last Report:

Bulletin No. 199—Treatment of Bovine Tuberculosis, by N. S. Mayo.
Bulletin No. 200—Chemical Studies of Virginia Soils, by W. B. Ellett and H. H. Hill.
Bulletin No. 201—Preparation of Concentrated Lime-Sulphur Solution on the Farm, by G. C. Starcher.
Bulletin No. 202—The Immediate Effect on Yield of Crossing Strains of Corn, by Lyman Carrier.
Bulletin No. 203—Experiments on the Control of the Cedar Rust of Apples, by H. S. Reed, J. S. Cooley and C. H. Crabill.
Bulletin No. 204—The Management of Blue-Grass Pastures, by Lyman Carrier and R. A. Oakley.
Bulletin No. 205—Summary of Ten Years Experiments with Tobacco, by E. H. Mathewson.
Bulletin No. 206—Experiments with Dark Tobacco, by B. G. Anderson.
Bulletin No. 207—Alfalfa Experiments, by Lyman Carrier.
Bulletin No. 208—Preparation of Nicotine Extracts on the Farm, by W. B. Ellett and J. Thomas Grissom.

Finances.

The General Assembly of 1914 made the following appropriations to the Virginia Agricultural Experiment Station for the ensuing biennium:

For experiments with tobacco and crops grown in rotation with tobacco	$7,500.00	annually
For District Experiment Stations	8,500.00	"

The Virginia Experiment Station also supervises the Experiment Stations conducted by the State Department of Agriculture at Staunton, Martinsville and Charlotte, and receives an appropriation from the State Board of Agriculture for that purpose. The present annual income of the Station is approximately as follows:

Federal Funds	Hatch Fund	$15,000.00
	Adams Fund	15,000.00
State Funds	Appropriation from General Assembly	16,000.00
	Appropriation from State Board of Agriculture	7,500.00
Sale of produce, etc.		2,000.00
Total income		$55,500.00

Agricultural practice in Virginia, as well as in other Southern States, is gradually undergoing a re-organization, due, among other causes, to the general awakening of the farmer to the advantages of modern crop methods. Incident to this reorganization, there are many demands upon the Experiment Station and other agricultural agencies for practical information about crop management and related subjects, upon which, data applicable to this region has not been accumulated. There are a number of lines of effort which are deserving of investigation, but which cannot be taken up at present, for the lack of funds.

As indicated above, the Station now receives money from the Federal Government for Experiment Station work, and from the State for County Experiment Stations and tobacco investigations. The funds received for the maintenance of the County Station and tobacco work, are barely sufficient for that purpose. These Stations are designed to make applicable to the community the results of experiments in this and other States. They are very necessary in a State with such diverse soil and climate as Virginia.

The use of the Adams Fund is restricted, by law, to the more fundamental problems of agriculture, the results of which will have a general application.

The Hatch Fund is largely used in paying the incidental expenses of the Experiment Station, and for publications. Experiments of the kind carried on with the Adams Fund are necessary, if agriculture is to progress. But this does not provide for the more immediate needs of the Virginia farmer.

Lines of Work for Which There is Pressing Need of Investigation.

Animal Husbandry and Grazing Experiments.—As pointed out in previous reports, there is need for information regarding the feeding and care of animals and the management of pastures. The agricultural practice in many communities is now undergoing a change, lands which have long been idle are being cultivated, and many large estates are being divided. With the knowledge that the keeping of all kinds of farm animals not only assists

in maintaining the fertility of the land but also in renovating old fields, there is a demand for definite information on all phases of the subject. The grazing lands in some parts of the State are increasing in value, so that the business of meat production is now conducted on a close margin, and some stockmen even suggest that a continued advance in real estate values will make beef production no longer profitable under the present methods. Farmers want information that is applicable to their particular community. Also, there are new feeds and new methods of handling stock, which are worthy of investigation. The Virginia Experiment Station has been able to do very little work along these lines, owing to the lack of funds. Many people speak of Virginia as a stock growing State, and the contour of the land in many of the counties is such that it is better adapted to stock raising than for general farming. An appropriation of $10,000 a year is needed for live stock and grazing investigations.

Poultry Husbandry.—The constant increase in the price of poultry products during the past decade has made the keeping of fowls an attractive undertaking in Virginia. There are already quite a number of commercial poultry plants in the State, and numerous people are engaged in raising fancy poultry. Many people are desirous of entering into the business of systematic poultry raising. Evidence of this fact is being constantly received at the Experiment Station, in the form of inquiries about poultry. This is an industry that appeals to the residents of small towns, as well as those living in the country. Every farmer should keep a flock of pure bred poultry. The poultry products of the State at the present time amount to a considerable item, but as a rule poultry keeping is not conducted as a business, and the product from the same number of fowls would increase three-fold if modern methods were adopted. The people already engaged in this business deserve some assistance from the State, and there is certainly no industry in which an investment would bring larger returns and benefit so large a number of people.

The establishment of a poultry plant at the Experiment Station is recommended, and an appropriation of $5,000 a year is needed for this purpose.

Soil and Crop Survey.—As noted in previous reports there is a constant demand upon the Station for information relating to the soils of the State. Farmers in Virginia are asking specific questions regarding the soils on their farms, and how maximum crop yields can be maintained. Prospective buyers are inquiring about the crop productiveness of the soil of certain districts as compared with the soils in other States. The physical character of the soil of several counties has already been mapped by the Bureau of Soils of the U. S. Department of Agriculture. There is need now of culture experiments, and observations on growing crops, supported by sufficient chemical work to determine the fertilizer needs and the crop producing pos-

sibility of the more common soil types in each community. Soil analyses should be made to determine the stock of plant food in every soil type. In connection with these surveys experiment fields should be conducted to determine by actual field tests how rapidly the plant food contained in the soil may be liberated under different systems of farming, and what is necessary to restore the various soils to fertility and maintain them in a permanently productive condition. Some information of this character is being accumulated by the County Experiment Stations. The situation demands, however, that the work be extended to include all the soil types found in the different sections of the State. An appropriation of $5,000 per year is needed to initiate the work.

PROJECTS AND EXPERIMENTS IN PROGRESS.

Detailed outline of projects and experiments in progress have been given in previous reports. Since the last report was issued, the following investigations have been completed or discontinued:

Effect of temperature on the blossoming of fruits.
Composition of blue-grass.
Association of leguminous and non-leguminous plants.
Acclimatization and breeding of field corn.
Treatment of stomach-worm and nodular diseases of sheep; and chronic diarrhœa of cattle.
Survey of beef and poultry production in Virginia.

The following new studies have been begun:

Study of some principles governing growth and maturity in corn.—This project has as its aim chiefly, the study of those factors which hasten or retard maturity of the corn plant. The first object of it will be to find, if possible, whether or not there is a relation between time and temperature of germination and subsequent growth and maturity. This will necessitate the finding of the optimum, maximum and minimum temperature of germination for numerous varieties as well as the relation of different sized kernels of the same variety to their time of germination under optimum conditions.

The effects of moisture, temperature and inorganic salts in their relation to maturity of the plants will also be studied.

The final phase of the problem will be the effect of hybridization on maturity.

The experiments are to be carried on in the greenhouse under control conditions, and paralleled in the field as far as possible.

Analysis and Preparation of Nicotine Sprays.—Large quantities of nicotine extract are now being used as a contact insecticide for the apple aphis and other sucking insects, and also as dips for cattle and sheep. The present high cost of the proprietary nicotine preparations has induced some farmers and fruit growers to substitute home-made tobacco decoctions for this pur-

pose. There is a demand for a more economical supply of nicotine than the market at present affords. This investigation has been initiated with the hope that some definite instructions could be given farmers which would enable them to make use of the waste tobacco products that occur on many Virginia farms.

Wintering Steers.—This project is designed to secure information on the best method of wintering steers that are to be finished on grass the following summer. One important phase is to determine the effect of silage as compared with dry feeds, and to note especially how the animals increase in weight after being placed on grass. There is a common notion among cattle men in grazing regions of this State that cattle wintered on silage do not do as well after being placed on grass as animals that have been fed on hay or corn stover. Some work of this nature was done at this Station several years ago, and the results published in Bulletin No. 164. The problem is of sufficient interest to justify further study.

Alfalfa Diseases in Virginia.—A preliminary survey of the alfalfa fields indicates that great losses are being sustained by alfalfa growers from diseases which are new or which are not well understood. The work contemplates a careful survey of the field and classification and study of the maladies of alfalfa with a view to the discovery of practical measures for their control.

Apple Tree Root Rot.—This disease is one of the most destructive in Virginia, and there is no method known by which it may be controlled. The observations that have been made indicate that root rot is more prevalent on new ground than on ground which has been cultivated for some years before the orchard is set, that it occurs on various kinds of soils, and that the white mycelium of a fungus is a constant accompaniment. It is proposed in this study to ascertain the real cause of the disease, its mode of attack and measures of control.

This study and the one above are considered a part of the general project of field experiments on plant diseases.

List of Projects and Experiments Conducted by the Virginia Agricultural Experiment Station.

HORTICULTURAL DEPARTMENT.

1. *Effect of soil environment on fruit-bud formation.
2. *Breeding late-blooming apples.
3. Studies of the laws of inheritance in garden vegetables.
4. Commercial value of Dwarf apples.
5. The control of fire blight.
6. Varietal studies of tree fruits.
7. Experiment orchards at five points in the State, for study of orchard spraying, fertilizing and soil management.

CHEMICAL DEPARTMENT.

1. *Fixation of phosphoric acid in soils.
2. The fertility of Virginia soils.
3. *Protein and energy requirements for milk production. (In coöperation with Dairy Husbandry Department.)
4. *Effect of green manuring on the soil.
5. Analyses and preparation of nicotine sprays.

AGRONOMY DEPARTMENT.

1. *Growth and maturity of corn.
2. Pasture management.
3. Cereal investigations.
4. Forage crop investigations, including experiments with soy beans and other field crops.
5. Alfalfa experiments.
6. Weed eradication.
7. Field experiments with farm crops—crop rotation and fertilizer experiments at Blacksburg and the nine (9) County Experiment Stations.

ANIMAL AND DAIRY HUSBANDRY DEPARTMENTS.

1. *Protein and energy requirements for milk production. (In coöperation with the Chemical Department.)
2. Forage crops for hogs.
3. Wintering steers.

PLANT PATHOLOGY AND BACTERIOLOGY DEPARTMENTS.

1. *Relation of parasitic fungi and bacteria to their host plant.
2. Principles of infection by uredineous fungi.
3. Plant disease survey of Virginia.
4. Field experiments on plant diseases. (Apple foliage diseases, root-rot of the apple, alfalfa diseases, tomato blight, cedar rust.)
5. Cause and control of peach yellows, in coöperation with the State Entomologist.
6. *Study of the organisms affecting the nitrogen compounds of the soil.
7. A chemical and bacteriological study of the different methods used in measuring the quality of milk.
8. Legume bacteria and inoculation.

WORK AT THE SUB-STATIONS.

The need of the Sub-Station work has been outlined in previous reports. A brief account of the work at each is given in the following paragraphs.

Appomattox, Appomattox County.—The U. S. Department of Agriculture has now withdrawn from the tobacco investigations initiated by the Bureau of Soils in 1904, and the experiments are being conducted by the Experiment Station. The main lines of work are fertilizer experiments for dark, fire-cured, shipping tobacco and the development of a rotation of crops which will constantly improve the fertility of the land. The results of the work for ten years have been summarized and published in Bulletin No. 205, from which the following significant statements are taken. There is a growing interest in the dark tobacco section in the production of other crops, and in other sources of income, than tobacco. As interest increases,

*Adams Fund projects.

the methods necessary for success will become better understood and the new industries may become relatively more profitable than tobacco. In the past the common method of growing tobacco was to follow tobacco with wheat. Clover was frequently sown in the wheat in early spring, but rarely was a good stand and good growth obtained. After the wheat harvest a semi-wild growth of weeds and bushes would spring up and after one or more years rest the field would likely be put back to tobacco. With a plentiful supply of cheap land, this may have been the best way, but as conditions are now this method is no longer profitable. It is now considered essential to provide a rotation that will include soil improving crops that will build up the land and at the same time increase the income per acre. In other words, the ten years observations in this community have shown that the methods used in growing tobacco yield only small net returns to the grower, and were at the same time depleting the soil. And, further, the experiments indicate that this condition can be remedied by crop rotation. B. G. Anderson is in charge.

Chatham, Pittsylvania County.—Experiments with bright tobacco have been in progress here since 1904. The main object of the work is to disprove the opinion common in the bright tobacco section that bright tobacco of good quality cannot be grown satisfactorily in connection with crops that enrich the soil. Results of the work of the Station are reported in Bulletin No. 198. J. C. Hart is in charge.

Axton, Henry County.—No experiments are conducted here, but acre plats of tobacco, wheat, grass, corn and cowpeas are grown to demonstrate the best results secured from the rotation and fertilizer experiments at Chatham, this being also in the bright tobacco district. J. C. Hart is in charge.

Bowling Green, Caroline County.—Experiments with sun-cured tobacco and the crops grown in rotation with tobacco, were begun here in 1908. Attention is directed chiefly to fertilizer and crop rotation work. Cultural experiments with the several crops in rotation, seed selection, and other experiment work of interest to the county are conducted. W. W. Green is in charge.

Louisa, Louisa County.—This work was begun in 1908. As at Axton, no experiments are conducted here, but acre plats of tobacco, wheat, grass, corn, cowpeas and red clover are grown to demonstrate the best results secured from the crop rotation and fertilizer experiments at Bowling Green. W. W. Green is in charge.

Staunton, Augusta County.—This station is supervised by the Experiment Station for the State Board of Agriculture. The main lines of work are crop rotation and soil fertility experiments adapted to Valley conditions. A five-year rotation of corn, potatoes, wheat, and grass (two years) has been adopted, and an extensive series of fertilizer experiments is conducted

on this rotation. Especial attention is given to a comparison of different sources of phosphoric acid, and various forms of lime.

The results of the work in alfalfa seem to justify the statement that it is more profitable to sow a light rather than a heavy rate of seed per acre, that is, about fifteen pounds instead of thirty. Also, that it is more profitable to sow alfalfa alone than in a mixture, and, that if alfalfa can be grown successfully, it is more profitable than any other hay crop. This Experiment Farm is favorably situated for the purpose, and should be of distinct service to Valley agriculture. J. M. Trimble is in charge.

Charlotte, Charlotte County.—This experiment work is supervised by the Virginia Experiment Station for the State Board of Agriculture. Special attention is given to tobacco culture in rotation with wheat, grass, corn, and cowpeas, and to tobacco breeding. The site selected for the experiment plats was a very poor land devoid of humus, much over-grown with bushes and broom-sedge. It had long been idle, and was characterized as worn-out land. The special reason for selecting poor land was to determine the feasibility of reclaiming the soil for agricultural purposes. Although the experiments have been in progress only a short time, the results indicate that by the use of complete fertilizers to start the crops, followed by green manures and applications of lime, profitable crops can be grown. D. D. Digges is in charge.

Williamsburg, James City County.—The twenty acres of plats here, established in 1912, are devoted chiefly to experiments with alfalfa and soil fertility. The series of fertilizer and soil fertility experiments is conducted on a six-year rotation of alfalfa (three years), corn, soy beans, winter oats or wheat. Special attention is given to problems in alfalfa culture, such as the rates of seeding, seeding with other legumes or grasses, liming, inoculation, and cultural methods. There is also a comparison of the availability of different phosphates.

Although this work has been in progress a short time, some noteworthy results have been secured. In a test to determine the effect of lime on the growth of alfalfa, the plats receiving no lime yielded as much, in four cuttings, as other plats, one of which received one ton burnt lime and another two tons of ground shells. In another test, in which twelve different fertilizer combinations were used for alfalfa, stable manure combined with acid phosphate gave the highest results. The next largest yield was secured by the use of stable manure alone. Wherever phosphorous was used either in the form of pure raw bone, acid phosphate or basic slag, the yield of alfalfa was increased. This test further indicates that this particular soil is well supplied with potash. R. P. Cocke is in charge.

Martinsville, Henry County.—The work at this point is conducted by the Virginia Experiment Station for the State Board of Agriculture. Spe-

cial attention has been given to a comparison of various crop rotations, a rotation of corn, soy beans, wheat, and grass (two years) being used on the fertilizer plats. In addition to the other work at Martinsville, there is now in progress a reclamation project which has attracted considerable attention. This is an effort to reclaim for agricultural purposes a hill-side field that has long been idle. The land in question was thin, badly gullied, and partly covered with scrub pines and other undergrowth. The pines and brush were cut off and thrown into the gullies, the banks of the gullies blown in with dynamite and leveled by hand labor. The land was partly plowed with a colter plow to cut and break the roots remaining after the undergrowth was removed, and the remainder of the field plowed with a turning plow. The entire tract was prepared and seeded to cowpeas. The object of this work is to accumulate data on the cost of putting a worn field into such shape that will permit the use of improved farm machinery. A. N. Hodgson is in charge.

Holland, Nansemond County.—Work was started here in 1914, to conduct cultural and fertilizer experiments on cotton and peanuts in rotation with other crops. Also experiments with varieties of cotton to determine the best variety for this region. E. T. Batten is in charge.

FIELD EXPERIMENT ORCHARDS.

The work noted in former reports on the experiments being conducted in cultivation, fertilization and spraying on bearing orchards in the State has been continued during the past two seasons. At the beginning of this year the work at Winchester was transferred to a new location and is at present located on the farm of Melvin Green, where fourteen-year old York Imperial apple trees have been selected for the purpose. Changes were made at Cloverdale in the John C. Moomaw Company orchard, where the cultural experiments were discontinued, and at Fishersville where, also the cultural experiments had to be abandoned, owing to an unprecedented early drouth which made it impossible to plow the plats in the orchard. The fertilizing and spraying experiments, however, were continued at this place.

The yield of fruit this year was very good in the Fishersville and Winchester orchards, but the prolonged drouth at Fishersville caused nearly one-half of the fruit to fall from the trees before harvesting time. The fruit left on the trees was in such poor condition that it was sold in bulk. The only notes secured was the total weight of the fruit of the various plats. Apparently the plats which had received nitrogen came through the season in much better condition than those on which no nitrogen was applied. The data cannot, however, be considered conclusive, since this is the first crop that has been secured in this orchard during the three years since the experiment began.

At Winchester the entire orchard was in vigorous condition at the beginning of the experiment, and while minor differences could be noted as a result of this year's work, yet no conclusion can be drawn. At Crozet the crop amounted to about 25 percent of a full crop as against 9 percent and 10 percent in the two preceding years. There was a very marked difference in the size of the fruit on the cultural plats as compared with the fruit on the sod and mulch plats. The apples on the former were much larger, but since the set of fruit was only 50 percent of that of the sod and mulch plats, there is only very little difference in the total yield in pounds. The yield, however, has been so light every year during this experiment that no final conclusions can be made. At Cloverdale there was about one-third of a crop of fruit on the orchard, and here again the plats which received nitrogen in manure or nitrate of soda seem to have had an advantage over the plats which received no nitrate.

The work is conducted by G. C. Starcher, under the general supervision of Professor H. L. Price.

Respectfully submitted,

W. J. SCHOENE, *Acting Director.*

REPORT OF THE TREASURER.

Federal Funds

From July 1, 1912 to July 1, 1913.

RECEIPTS	HATCH FUND	ADAMS FUND	SUPPLEMENTAL FUND
Balance 1912, corrected	$ 12.10	$ 2.19	$ 1,523.58
Treasurer United States	14,987.90	14,997.81	....
Sundry sales	....	....	2,081.95
Bank, for interest on balances	....	....	141.80
Totals	$ 15,000.00	$ 15,000.00	$ 3,747.33
DISBURSEMENTS			
Freight and express	$ 114.52	$ 114.37	$ 8.51
Postage and stationery	528.39	39.13	3.00
Printing	1,766.65	....	2,250.92
Library	506.39	3.48	3.00
Salaries	7,866.96	9,414.56	....
Tools, machinery, etc.	302.00	192.95	....
Furniture and fixtures	74.65	34.75	....
Live stock	480.50	451.50	....
Traveling expenses	302.85	279.45	61.00
Repairs and lands	134.22	220.53	....
Contingent	40.00	125.00	2.10
Heat, light and water	....	70.09	....
Seeds, plants and supplies	389.16	428.21	....
Fertilizers	17.85	84.09	17.00
Chemical supplies	33.66	405.98	3.54
Feed stuffs	143.05	849.89	....
Scientific apparatus	85.05	539.61	....
Labor	2,214.00	1.746.41	33.77
Balances	.00	.00	1,364.49
Totals	$ 15,000.00	$ 15,000.00	$ 3,747.33
Balances, July 1, 1913	.00	.00	1,364.49

CHAS. I. WADE, Treasurer.

From July 1, 1913 to July 1, 1914.

RECEIPTS	HATCH FUND	ADAMS FUND	SUPPLEMENTAL FUND
Balance, July 1, 1913	....	....	$ 1,364.49
Treasurer United States	$ 15,000.00	$ 15,000.00	....
State fund transferred	....	....	825.00
Sundry sales	....	....	1,753.65
Bank for interest	....	....	139.79
Totals	$ 15,000.00	$ 15,000.00	$ 4,082.93
DISBURSEMENTS.			
Freight and express	$ 285.20	$ 136.32	$ 3.44
Postage and stationery	442.34	66.41	122.05
Printing	43.50	....	829.44
Library	244.00	....	....
Salaries	9,272.55	9,019.72	100.00
Tools and implements	134.99	34.13	30.10
Furniture and fixtures	388.94	236.17	.45
Traveling expenses	326.68	345.65	32.21
Repairs and buildings	95.05	355.30	989.39
Contingent	42.00	....	125.00
Heat, light and water	17.83	91.30	4.16
Seeds, plants and sundries	568.83	387.35	68.56
Fertilizers	125.80	269.81	36.50
Chemical supplies	41.60	487.28	63.61
Feed stuffs	786.84	610.71	533.54
Scientific apparatus	216.93	526.52	....
Labor	1,964.24	2,433.03	719.37
Balances	2.68	.30	425.11
Totals	$ 15,000.00	$ 15,000.00	$ 4,082.93
Balances, July 1, 1914	2.68	.30	425.11

CHAS. I. WADE, Treasurer.

STATE FUNDS

From July 1, 1913 to July 1, 1914.

RECEIPTS	STATE FUND	STATE BOARD AGRICULTURE FUND
Balance July 1, 1913	$ 837.86	$ 96.13
State appropriation, tobacco experiments, 1913-14	3,333.34	....
" " " " 1914-15	2,833.32	....
" " district " 1913-14	3,333.34	....
" " " " 1914-15	2,500.00	....
Sundry sales	715.80	757.07
Bank interest on balances	37.51	20.10
Commissioner Koiner, July 1, 1913, to January 1, 1914	....	5,500.00
Same, January 1, 1914, to July 1, 1914	....	3,750.00
Totals	$ 13,591.17	$ 10,123.30

DISBURSEMENTS		
Freight and express	$ 28.16	$ 104.18
Postage and stationery	52.37	82.79
Printing	28.00	....
Library	3.00	....
Salaries	7,209.83	2,226.62
Tools and implements	243.10	673.62
Furniture and fixtures	24.00	....
Live stock	235.00	616.50
Traveling expenses	1,074.38	513.71
Buildings and repairs	321.48	1,513.97
Contingent	437.39	102.78
Seeds, plants and sundry supplies	647.76	614.91
Fertilizer	1,058.32	568.97
Feed stuffs	38.25	80.85
Labor	2,166.30	1,950.87
Balances	23.83	1,073.53
Totals	$ 13,591.17	$ 10,123.30
Balances on hand July 1, 1914	$ 23.83	$ 1,073.53

CHAS. I. WADE, Treasurer.

From July 1, 1912 to July 1, 1913.

RECEIPTS	STATE FUND	STATE BOARD AGRICULTURE FUND
Balance report July 1, 1912	$ 963.79	$ 412.73
State appropriation, tobacco experiments, 1912-13	3,333.35	....
" " " " 1913-14	1,666.66	....
" " district " 1912-13	3,333.34	....
" " " " 1913-14	1,666.66	....
Sales	993.49	....
Virginia State Horticultural Society	53.35	....
Bank for interest	30,68	....
Commissioner Koiner	....	3.000.00
Sales	....	125.66
Totals	$ 12,041.32	$ 3,538.39

DISBURSEMENTS		
Freight and express	$ 105.47	$ 11.08
Postage and stationery	107.22	49.66
Printing	717.65	....
Salaries	5,938.18	1,275.00
Tools and implements	219.70	230.20
Live stock	395.00	....
Traveling expenses	1,028.09	248.57
Repairs and buildings	....	6.00
Contingent	135.35	29.95
Seeds, plants and sundry supplies	490.18	399.18
Fertilizers	519.94	53.90
Feed stuffs	42.74	105.46
Labor	1,503.94	1,033.26
Balances	837.86	96.13
Totals	$ 12,041.32	$ 3,538.39
Balances on hand, July 1, 1913	$ 837.86	$ 96.13

CHAS. I. WADE, Treasurer.

Department Reports

REPORT OF THE HORTICULTURIST.

Mr. W. J. Schoene, Acting Director.

SIR: I have the honor to submit herewith a report of the work of the Horticultural Department for the years 1912-13 and 1913-14.

The Adams fund projects outlined in previous reports have been continued. In the breeding of late blooming varieties additional crosses have been made and a considerable amount of cross bred seed has been secured. The study of the effect of soil environments on the formation of the fruit buds is progressing favorably. An irrigation system has been installed on the high moisture series of plats in the Blacksburg orchard which gives a more complete control of the moisture content of the soil. Observations have been made on the fruit buds of the three varieties of peaches of the different plats to determine their relative resistance to winter killing. This study promises interesting results, although it must continue over a number of years to warrant reliable conclusions. The effect of pruning trees at different times in the season and the bearing of such practice on the problem of the soil environment has been studied by Mr. A. W. Drinkard, Jr. The result of this study is submitted for publication as a separate paper in this report.

The hybridization work with cabbage and certain ornamental plants has been continued. Additional crosses with phlox have been made and the hybrid cultures are now under observation.

The various field experiments established under State funds have been continued. The work at Winchester was transferred to a new location last spring and the field experiments located at Fishersville and Cloverdale have both been simplified. The fertilizer experiments at all of these points have been continued. At Crozet the work has been carried out as orginally planned and although the crop was a light one this year the records on yield and keeping quality indicate that if the study can be continued it will yield interesting and important results.

Considerable attention has been paid during the last two years by Mr. G. C. Starcher to packing and marketing problems with special reference to the peach. The results of this study have been presented for publication.

Some additional work has been done in the study of varieties and their adaptation to certain locations in the State. A large body of data bearing on the problem of variety adaptation has gradually accumulated.

Very respectfully,

H. L. PRICE, *Horticulturist.*

REPORT OF THE CHEMIST.

Mr. W. J. Schoene, Acting Director.

SIR: I have the honor to submit the following report for the Department of Chemistry.

The Adams fund projects of the department have been continued.

The field and laboratory studies of the fixation of phosphoric acid are yielding results and indicate that the solvent used will show the approximate availability of the different phosphates when applied to soils. Experiments conducted with different soils, and the result of fixation of phosphoric acid with different substances, did not yield concordant data. This was due to external causes which we think can be eliminated during the coming season.

The green manuring project formerly in co-operation with the Department of Bacteriology is now being conducted by the Department of Chemistry. Laboratory, pot and field experiments are being conducted along Bacteriological and Chemical lines. This report includes an article showing "The effect of green manuring on soil nitrates under greenhouse conditions," which treats of one phase of the subject.

The feeding experiment with dairy cows in co-operation with the Department of Dairy Husbandry is still being conducted. The feeding period will be lengthened from 75 to 150 days, but all the rations will be interchanged as they were last year. Thus each cow will receive each ration for 50 days. The excess protein ration will be followed by the basal ration and the latter will be followed by the excess carbohydrate ration. The last 10 days of each period, digestion experiments will be carried on. The long feeding experiments with high and low protein rations are also continued.

Some chemical work has been done for other departments of the station. The chemical department conducted experiments in co-operation with the State Entomologist on nicotine as an insecticide and published in Bulletin No. 208 on this subject.

The work on Blue-Grass and the association of Legumes and Non-Legumes is included in an article in this report.

Respectfully submitted,

W. B. ELLETT, *Chemist.*

REPORT OF THE PLANT PATHOLOGIST AND BACTERIOLOGIST.

Mr. W. J. Schoene, Acting Director.

SIR: I have the honor to present herewith a report on the work of the department of Plant Pathology and Bacteriology for the years 1912-13 and 1913-14.

Upon the resignation of the Bacteriologist, Dr. E. B. Fred, on September 15, 1913, the department of bacteriology was combined with that of plant pathology, and placed under my direction. Work on the several projects outlined has gone forward, and I am able to report that some of them have been completed.

The Plant Disease Survey, in co-operation with the U. S. Department of Agriculture, has been continued, and further information upon the plant diseases of the State and their prevalence has been accumulated. From time to time we shall report upon the progress of this work.

The projects on the control of spinach disease, of infection by Uredineous fungi, and of cabbage club root, have been discontinued.

The Cedar Rust work has claimed a large share of our attention. The need for information upon which to base our practices has justified this work, and the apple growers have shown a keen interest in the work which we have done.

Further work on the tomato blight and rot has taken the form of a joint project with the Horticultural Department of this station, and we are endeavoring to breed some tomatoes which will be resistant to these diseases. We have on hand at this writing a quantity of seed from plants which show promising indications.

Studies of the fungi associated with the Frog Eye leaf spot of the apple have been continued. Many new questions have arisen in the course of this study and it will probably require some time for their ultimate solution.

The study of the effect of fungi upon their hosts, supported by the Adams Fund, has been carried on and some papers have been published, showing the nature of chemical changes which digestive enzymes of the fungi produce in the constituents of the fungus itself.

In co-operation with the State Entomologist, the work on Peach Yellows has been continued. A report upon the nature of the chlorophyll compounds of the peach leaf is now ready for publication.

The question of the best inoculating material for use in inoculating leguminous seed or soil has been under study for several years and a bulletin has been prepared upon this subject, which is now ready for publication.

An extensive study has been carried on to learn the nature of the bacteriological processes in the soils of the State. Nitrogen fixation and nitrification have been studied in samples of a large number of soils from dif-

ferent parts of the State. As a result of this work, we are in a much better position to advise constructive work in soil fertility building than before. A report of this work is ready for publication.

The relation of soil organic matter to the nitrogen fixing powers and growth of Azotobacter has been carried on and results are likewise ready for publication. Further work is under way upon this question. The failure of many soils to show the presence of this organism has been quite apparent in our previous studies. It is highly desirable to learn the causes of this bad condition and to learn how to remedy them, if possible.

The fate of bacteria in milk at different temperatures is a question which is of great interest to those interested in the shipment and storage of milk and cream. The study of the activities of certain species of bacteria at different temperatures has been accomplished. These results will soon be ready for publication.

Since the appearance of the 1911-12 report of the Experiment Station, the following papers have been published from this laboratory:

The Effect of Diplodia zeæ and some other fungi upon some phosphorus compounds of Maize. H. S. Reed, N. Y. Med. Jour., March 22, 1913.

Is the Phytophthora of the Potato identical with that of the Tomato? Howard S. Reed, Phytopathology. 2:250. 1912.

Plant Diseases in Virginia in the Years 1911 and 1912. Howard S. Reed and C. H. Crabill. Ann. Rep't. Va. Agr. Exp. Sta., 1911-12.

The Enzyme Activities Involved in Certain Fruit Diseases. Howard S. Reed. Ann. Rep't. Agr. Exp. Sta., 1911-12.

The Winter Resistance of the Uredospore of Puccinia coronata Cda. Howard S. Reed and F. S. Holmes. Ann. Rep't. Va. Agr. Exp. Sta., 1911-12.

The Effect of the Cedar Rust Fungus upon the transpiration of Apple Trees. Howard S. Reed and J. S. Cooley. Ann. Rep't. Va. Agr. Exp. Sta., 1911-12.

The Effect of Cedar Rust upon Assimilation of Carbon Dioxide by Apple Leaves. H. S. Reed and J. S. Cooley. Ann. Rep't. Va. Agr. Exp. Sta., 1911-12.

The Transpiration of Apple Leaves infected with Gymnosporangium. H. S. Reed and J. S. Cooley. Bot. Gaz. 55:421. 1913.

Studies on Phyllosticta and Coniothyrium occurring on Apple Foliage. C. H. Crabill. Ann. Rep't. Va. Agr. Exp. Sta., 1911-12.

The Production of Secondary Sporidia by Gymnosporangium. C. H. Crabill. Phytopathology, 3:282. 1913.

Experiments on the Control of the Cedar Rust of Apples. H. S. Reed. J. S. Cooley and C. H. Crabill. Bulletin No. 203. Va. Agr. Exp. Sta.

Methods for demonstrating the Biochemical activities of Micro-organisms. (In press.) C. H. Crabill and H. S. Reed.

The Formation of Hexone and Purine Bases in the Autolysis of Glomerella. Howard S. Reed. Jour. Biol. Chem., 19:257. 1914.

Very respectfully,

HOWARD S. REED,

Plant Pathologist and Bacteriologist.

REPORT OF THE AGRONOMIST.

Mr. W. J. Schoene, Acting Director.

SIR: I have the honor to submit the following report for the Department of Agronomy.

Cereal Investigations.—This work was begun in 1908 and includes variety tests, selection and hybridization with the idea in view of finding out which of the commercial varieties of small grain now sold in the State are best for the various localities, and, if possible, to produce strains better suited to the different conditions.

Wheat.—The chief work done with wheat to the present time has been in making variety test and individual head selections. At the present time our experiments seem to indicate that Fulcaster, Leap's Prolific, Harvest King, and Mediterranean are among the best commercial varieties. Some of the strains resulting from the individual head selections seem to be superior to any of the commercial strains. These are now in increase plats and if they continue superior to the commercial varieties will be distributed to the farmers next season. A number of pure lines have been planted in the greenhouse for hybridization purposes and work with these hybrids will be a large part of the wheat investigations in the future.

Oats.—The oat work has been very similar to that with wheat. At the present time we are distributing a variety of winter oats which was produced by the individual head selection method.

Rye and Barley.—Variety tests are being carried on with rye and barley in an endeavor to find the most suitable varieties for further work.

Corn.—Work is being carried on in the improvement of seed-corn by selection. Each year a small field of our best selection is grown for distribution. The department distributes to the farmers from 100 to 200 bushels of improved corn each year. An Adams Fund project is being started to

determine the factors governing the growth and maturity in corn, and work is also being carried on to determine the value of the first generation hybrid as seed corn.

Pasture Management.—The work on pasture management in co-operation with the United States Department of Agriculture, which was commenced in 1908 and reported on in Bulletin No. 204 of this Station, is being continued. The chief phase of the work studied at the present time is the effect of fertilizers on pastures and methods of weed eradication. The effect of light and heavy grazing and that of alternate and continued grazing is also being studied.

Forage Investigations.—Tests are being made with soy beans, cowpeas, buckwheat, millets, sorghums, Sudan grass, clovers and the perennial grasses, to determine their value as hay, silage and grain producers. Work is also being done to determine the best cultural methods for the above crops.

Potato Studies.—Extensive studies are being made to determine the best varieties of potatoes to plant for both the early and the late crop. Selections are being made by the " tuber unit " method, and work is being done to determine the best method of preparing seed potatoes.

Alfalfa Experiments.—Experiments are being started to determine the best dates and rates of seeding alfalfa; whether it is better to seed it alone or in mixtures, and to determine the best methods of fertilizing, cultivating and inoculating it. Test will also be made of the different strains with the idea in view of developing a strain which will produce a profitable yield of both hay and seed.

Rotation and Fertilizer Experiments.—These experiments are being carried on in co-operation with the Department of Chemistry, and will be reported by the chemist.

Respectfully submitted,
THOMAS B. HUTCHESON, *Agronomist.*

REPORT OF THE ANIMAL HUSBANDMAN.

Mr. W. J. Schoene, Acting Director.

SIR: I have the honor to submit the following report from the Department of Animal Husbandry:

The Adams Fund project (to determine the protein and energy requirements for milk production and the effect of continuous wide and narrow rations upon the individuals, their milk production, and offspring), is being conducted as outlined in co-operation with the Department of Chemistry.

Definite conclusions have not been drawn, but the indications are that by additional protein the milk production may be increased.

The Hatch Fund project is a steer feeding project in which we will feed a common ration of corn stover and corn meal, corn silage alone, and one pound of cottonseed meal with corn silage, so that the steers will lose about 50 to 60 pounds each during the feeding period. The fourth lot will be fed one pound of cottonseed meal and enough silage so that they will gain from 25 to 30 pounds during the winter. The fifth lot will be fed less silage than lot four, but the same amount of cottonseed meal. These steers will not gain any and shall not lose more than 25 pounds each during the winter.

The five lots of steers will be grazed on the same pasture next summer and will be weighed when they go off of grass pasture next fall. We shall determine the cost of gain from the time they are taken off of pasture this fall until they are sold. This should give us some information as to the effect of silage feeding and the gains made on grass pasture the following summer, which is very important to stock raisers in this section.

We shall also continue the work started by Doctor Mayo—Forage Crops for Hogs with Supplementary Feeds. This work will be carried on mostly at the Sub-Stations, but will be under the direction of this Department. From the data gathered by Doctor Mayo we are lead to believe that some of the forage crops that have been used are not profitable for raising hogs, and we propose to use blue-grass pasture, rape sowed at various periods during the season, some leguminous crops such as velvet bean or red clover, and the rotation recommended by the farm demonstrators of this State.

Respectfully submitted,

R. E. Hunt, *Animal Husbandman.*

REPORT OF THE LIBRARIAN.

Mr. W. J. Schoene, Acting Director.

Sir: The volumes in the Library number 8,965; pamphlets 40,301.

The Experiment Station Library subscribes to the following periodicals:

American Naturalist.
Biological Bulletin.
Biometrika.
Botanical Gazette.
Botanisches Centralblatt.
Berichte d. deut. Bot. Gesellschaft.
Bulletin Society Mycolog. de France.
Centralblatt f. Bakteriologie.
Comptes Rendus.
Jahresbericht f. Agric. Chemie.
Jahresbericht u Garungs-Organismen.

Jahresbericht u Pflanzenkrankheiten.
Journal of Agricultural Science.
Journal of American Soc. of Agronomy.
Journal of Experimental Zoölogy.
Journal of Economic Entomology.
Journal of Genetics.
Journal of Hort. Society of New York.
Journal of Industrial and Eng. Chemistry.
Journal f. Landwirtschaft.
Journal of Royal Agricultural Society.
Kryptogamen Flora.
Landwirt. Jahrbucher.
Landwirt. Versuchs-Stationen.
Mycologia.
New Phytologist.
Phytopathology.
Plant World.
Psyche.
Zeitschrift f. Botanik.
Zeitschrift f. Pflanzenkrankheiten.
Zeitschrift f. Physiol. Chemie.
Zeitschrift f. Unter. Nahr. u Genussmittel.

EXCHANGES RECEIVED BY LIBRARY

American Bee Journal.
American Breeder.
American Fertilizer.
American Florist.
American Poultry Advocate.
American Poultry World.
American Journal of Veterinary Medicine.
American Sheep Breeder and Wool Grower.
Berkshire World.
Better Fruit.
Big Four Poultry Journal.
Breeders' Gazette.
Chicago Dairy Produce.
Cold.
Country Gentleman.
Countryside Magazine.
Elgin Dairy Report.
Farm and Fireside.
Farming Business.
Farm Journal.
Farmers' Digest.
Farmers' Home Journal.
Farmers' Review.
Farm Stock and Home.
Farm Engineering.
Farmer's Wife.
Farmers' Guide.
Flour and Feed.
Field and Farm.
Fruit Grower and Farmer.
Gleanings in Bee Culture.
Gas Power.
Green's Fruit Grower.
Guernsey Breeders' Journal.
Harvester World.
Hoard's Dairyman.
Home and Farmstead.
Horse World.
I. C. S. Farmer and Poultryman.
Independent Farmer.
Indiana Farmer.
Kansas Farmer.
Kimball's Dairy Farmer.
Mark Lane Express Agr. Journal.
Market Growers' Journal.
Medical Freedom.
Milk Dealer.
National Grange Monthly.
National Stockman and Farmer.
New York Produce Review.
Nut Grower.
Ohio Farmer.
Oklahoma Farm Journal.
Pacific Dairy Review.
Practical Farmer.
Progressive Farmer.
Reliable Poultry Journal.
Saddle and Show Horse Chronicle.
Southern Ruralist.
Southern Fruit Grower.
Southern Planter.
Southwest Trail.
Successful Farming.
Successful Poultry Journal.
Texas Stockman and Farmer.
Threshmens' Review and Power Farming.
Trade.
Vegetable Grower.
Wallace's Farmer.
Western Farm Life.
Western Empire.

FOREIGN EXCHANGES

Argentina.
Agricultural Gazette of Canada.
Agricultural Gazette of New South Wales.
Agricultural Journal of India.
Agricultural Journal of Union of South Africa.
Hawaiian Forester.
International Institute of Agriculture, Bulletin.
Journal of Department of Agriculture of South Australia.
Journal of College of Agriculture of Tokyo.
Journal of Department of Agriculture of Victoria.
Journal of Department of Agriculture of New Zealand.
New Zealand Dairyman.
O Criador Paulista.
Philippine Agricultural Review.
Revista Industrial.

Accessions during the two years amount to 315 volumes. Efforts have been made to complete the files of The Southern Planter, early numbers of which are hard to obtain. We are glad to state that seventeen broken volumes dating back to the year 1844 were recently presented by Prof. W. D. Saunders, of this place.

Respectfully submitted,
ANNA E. MURRILL, *Librarian.*

THE EFFECT OF THE ASSOCIATION OF LEGUMES AND NON-LEGUMES.

By W. B. Ellett, H. H. Hill and W. G. Harris.

Analyses made by the chemical department of the Virginia Experiment Station during the past six years on the grasses growing in Virginia indicate that Kentucky blue-grass has a higher percentage of protein than is usual for that grass. This fact was pointed out in Bulletin No. 180 of this station, and we believe that the farmers have a just claim when they say the Valley and Southwest Virginia are as good as, if not better for grazing cattle than other sections of the country. They contend that the growth of the grass is superior and that it is more palatable to stock. It is a known fact that the Southwest and the Shenandoah Valley are among the few localities of the country where export beef cattle can be finished on blue-grass alone.

Investigations[1] by this department show the high protein content to " hold-up " well above the limits in protein percentage given for the typical grass, some of the grass samples analyzing above 25 percent protein.

Object of the Experiment.

The object of this experiment was to account for the high percentage of protein in the samples of grass grown in Virginia. We believe that the composition of the grass grown elsewhere has been underestimated and the cause of this fact is due to the analyses having been made on more mature grass or at the time best suited for making hay.

In most of the blue-grass samples from Southwest Virginia we found that the sod contained an admixture of white clover. Can it be that this leguminous plant affects the protein content of the blue-grass, or can this high percentage of protein be attributed to some peculiar effect of the soil and climate upon its composition, or is there some other factor which gives to this grass the high feeding value claimed for it?

A review of the literature shows that many experiments have been made which conclusively prove that leguminous plants obtain a part of their nitrogenous plant food from the air, thereby differing from the non-legume in this respect. Storer,[2] commenting on this question, says: " Grasses may get some good from the secretion of the micro-organisms which the clover supports."

[1] Va. Agr. Exp. Sta. Bul. No. 180.
[2] Storer. Agr. Chem. p. 539.

Lipman,[1] Lyon and Bizzel,[2] and others, have shown by their experiments that in some cases legumes benefit non-legumes when grown with them. They all recognize the importance of including crops of this nature in a rotation, yet they have not proved that a legume influences the protein content of the non-legume, except in special cases. That the altitude and climate may affect the composition of grasses has been shown by experiments conducted in Wyoming.[3] In the sections of Virginia where the Kentucky blue-grass grows best the altitude is high and the soil is of limestone origin and the climate is apparently favorable. We have found on reviewing some of the unpublished analyses made by the Virginia Experiment Station in co-operation with the Office of Forage Crop Investigations of the U. S. Department of Agriculture, that when samples of young grass were cut at different periods of the year, the young blue-grass contained on an average about 4 percent more protein than when cut for hay at maturity.

Analyses of the amide nitrogen in the young and mature grass did not account for the differences, as relatively the same amounts were present. The samples did not show the presence of nitrates. This leads us to believe that the high protein content must be due to either the presence of legumes or the non-maturity of the grasses when sampled.

Huston and Jones[4] have shown that the percentages of nitrogen in wheat and corn are smaller at the time of harvest than at younger stages of their development, although the total yield of protein was greater at harvest.

This same idea has been advanced by Crozier,[5] of the Michigan station, and results are quoted to show that hay is more valuable than the pasture grass.

Lipman[6] called attention to the diffusion of nitrogen compounds through unglazed porous pots, and his results show that non-legumes were benefited by the association with legumes. He found that when peas were planted in an outer pot and oats planted in an inner porous pot, the oats derived some soluble nitrogenous compounds which were diffused through the unglazed porous wall of the pot. In order to study the effect of a legume on a non-legume when planted with and adjacent to non-legumes, on the protein content of the non-legume, we conducted the following experiments.

Plan of Experiment.

Concrete Basin.—We selected the center aisle of one of the greenhouses, which was divided into three equal sections or plats, by two four-inch con-

[1] N. J. Agr. Exp. Stat. Bul. No. 253.
[2] Cornell University Agr. Exp. Sta. Bul. No. 294.
[3] Wyoming Exp. Sta. Bul. No. 87.
[4] Ind. Agr. Exp. Sta. Bul. No. 175.
[5] Mich. Agr. Sta. Bul. No. 141.
[6] Jour. Agr. Sci. Vol. III. Part III.

crete walls. Each section was again sub-divided into three equal plats; between the first and second plats a division of four-inch concrete was made and between two and three a space of four inches of soil was left so that diffusion of organic nitrogenous substances might take place if water was supplied and had to pass through Plat 2 before reaching Plat 3.

This concrete basin was filled within ten inches of the top with coal ashes and then filled with Hagerstown loam soil from Blacksburg, Virginia.

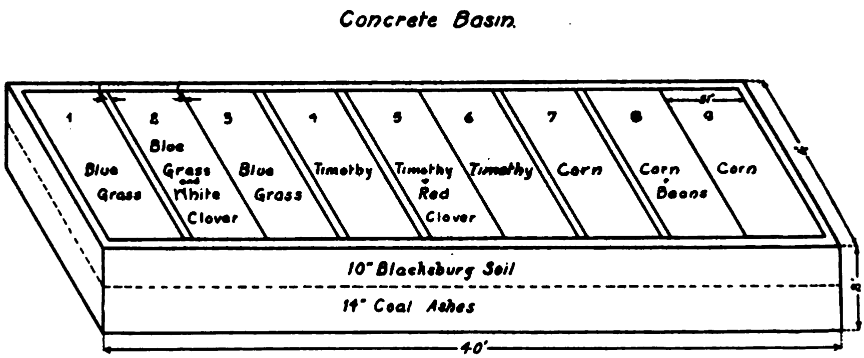


Fig. 1.—Experiment on the association of legumes with non-legumes.

Experiments With Blue-Grass and White Clover.

On January 1, 1911, Plats Numbers 1, 2 and 3, were sown with equal quantities of Kentucky blue-grass. On Plat 2 some white clover seed was added. Apparently equal stands of grass were obtained and the first cuttings were made on March 1st, when the grass was about five inches high. We decided to cut only one-half of each plat so that the other half would come nearer maturity and the analyses would show what effect, if any, the age would have on the composition.

TABLE I.—*Percent and Yield of Protein on Plats 1 and 3.*

DATE OF CUTTING	Plat 1		Plat 3	
	Blue-grass		Blue-grass separated from Plat 2 by four inches of soil	
	PERCENT PROTEIN	GRAMS PROTEIN	PERCENT PROTEIN	GRAMS PROTEIN
Mar. 1, 1911	32.71	43.24	31.65	55.58
Apr. 1, 1911	24.37	37.26	24.53	45.21
May 1, 1911	25.27	77.38	22.78	38.43
June 1, 1911	18.20	52.58	14.88	43.98
Dec. 1, 1911	19.93	106.50	15.92	71.56
Feb. 4, 1912	16.91	41.60	22.76	57.45

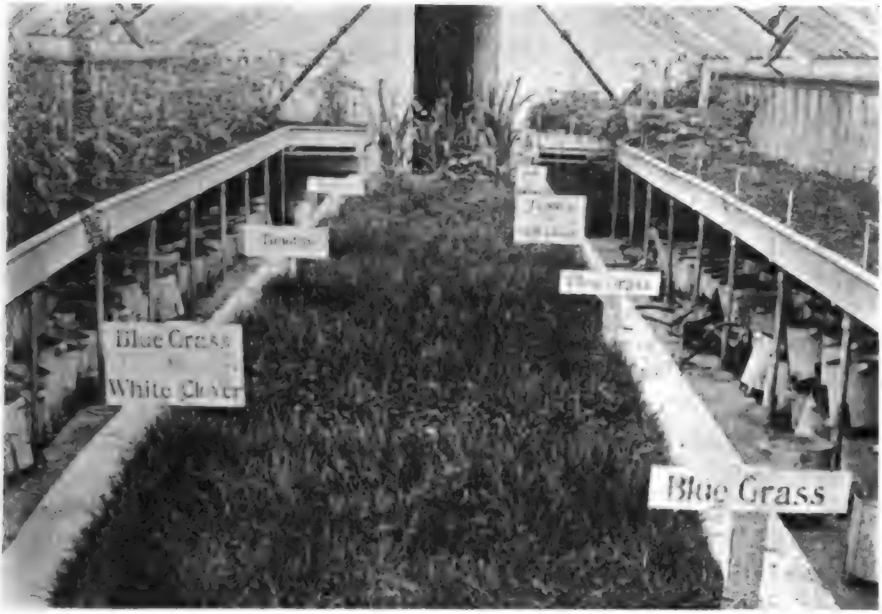


Fig. 2.—Experiments with blue-grass and white clover.

The cuttings made of Plats 1 and 3 on March 1st, after the grass had only been sown three months, show about equal percentages of protein, yet the yield of protein was greater on Plat 3 than it was on Plat 1, although Plat 3 was adjacent to Plat 2, which was sown with a mixture of white clover and blue-grass. No benefit could have been derived from being adjacent to the legume as the nodules were not developed. The cutting made April 1st shows a decrease in the percentage of protein and indicates that the older the grass the less protein it contains.

The grass did not grow very well after June 1st, and we decided to discontinue the cutting until cooler weather.

The whole plats were cut on December 1, 1911, and again on February 4. 1912. the total yield of protein of Plat 1 being 358.56 grams, and on Plat 3. 312.21 grams. Apparently no effect was shown either on the percent of protein or on the total yield by being adjacent to a legume, although the nodules were well developed. The clover plants must have been assimilating some nitrogen from the air.

Plat 2 was cut at the same time as the other plats. The total yield of protein was 339 grams. Samples of blue-grass were separated from the clover and did not show any increased percent of protein, than when the blue-grass was grown alone.

The experiment was repeated in 1913. The plats were reseeded and cuttings made. The results are given in Table 2.

TABLE II.—*Protein Content of Blue-Grass When Grown Alone, Adjacent to, And With a Legume.*

DATE OF CUTTING	Plat 1	Plat 2	Plat 3
	Blue-grass alone	Blue-grass grown with white clover	Blue-grass separated from white clover by four inches of soil
	PERCENT PROTEIN	PERCENT PROTEIN	PERCENT PROTEIN
Dec. 1, 1913	33.35	30.23	32.99
Feb. 1, 1914	28.61	30.32	28.83
Apr. 7, 1914	20.13	22.18	19.08
June 8, 1914	14.83	15.84	14.37
Average	24.21	24.64	23.82

These results do not indicate that the presence of clover influenced the protein content of blue-grass, either when grown with it, in the same plat, or adjacent to where clover was grown.

The yield of protein is not given in the table because the stand of grass was not equal in the different plats.

The first two cuttings show that abnormally high percentages of protein were present, and prove that immature blue-grass has a higher percentage of protein than it has at later periods of its development.

Experiments With Timothy and Red Clover.

At the same time the blue-grass experiments were started, Plats 4, 5 and 6 were sown with timothy, timothy and red clover, and timothy respectively.

The same quantity of timothy seed was sown on the three plats.

TABLE III.—*Protein Content of Timothy When Grown Alone, Adjacent to, And With a Legume.*

DATE OF CUTTING	Plat 4	Plat 5	Plat 6
	Timothy alone	Timothy grown with red clover	Timothy separated from red clover by four inches of soil
	PERCENT PROTEIN	PERCENT PROTEIN	PERCENT PROTEIN
Mar. 1, 1911	30.27	25.21	24.61
Apr. 1, 1911	24.35	27.29	24.70
May 1, 1911	24.68	17.32	18.49
June 1, 1911	18.59	....	17.19
Average	24.47	23.27	21.25

The results do not indicate that clover benefited the timothy or had any effect on the protein percentage.

The amounts of protein produced on Plats 4, 5 and 6, were 264, 274, and 231 grams, respectively. This shows that the total yield of protein was greater when clover was present on Plat 5.

The plats were not cut after June, 1911. The clover was allowed to come to maturity on Plat 5 and in the fall of 1912 the plats were spaded up and re-seeded.

TABLE IV.—*Protein Content of Timothy When Grown Alone, Adjacent to, And With a Legume. 1913 and 1914.*

DATE OF CUTTING	Plat 4	Plat 5	Plat 6
	Timothy alone	Timothy and red clover	Timothy separated from clover by four inches of soil
	PERCENT PROTEIN	PERCENT PROTEIN	PERCENT PROTEIN
Dec. 1, 1913	27.31	30.08	26.20
Feb. 1, 1914	31.41	32.81	28.72
Mar. 15, 1914	22.40	29.83	21.40
Apr. 17, 1914	16.66	24.53	19.49
June 8, 1914	13.45	17.66	13.74
Average	22.24	26.98	21.91

The timothy grown on Plat 5 was taller and had a better color and grew more luxuriantly than on Plats 4 and 6. The protein content was greater and apparently the timothy either profited by the association of the legume or drew upon the nitrogen that was stored up in the soil by the clover.

In these experiments the protein is abnormally high, yet after each cutting new growth would start and continue green. The analysis represents the young growth, except the cutting which was made on June 8th. Here the protein content has materially decreased in all of the plats, due to the samples being more mature.

Results With Corn and Beans.

Plats 7, 8 and 9 were planted with corn, corn and beans, and corn, respectively. When the plants in the three plats were about five inches high, the corn was thinned so that each plat would have the same number of corn plants. When the plants had ceased to grow and had reached maturity, the plants were cut and ground for analysis.

Fig. 3.—Effect of association of corn with beans in green-house experiment.

TABLE V.—*Dry Matter and Nitrogen in Corn When Grown Alone, Adjacent to, And With a Legume.*

Plat NO.		Dry matter produced POUNDS	Nitrogen PERCENT
7	Corn alone, separated by concrete wall	4.25	1.73
8	Corn grown with beans	8.00	2.05
9	Corn grown adjacent to beans, separated by four inches of soil	6.50	1.63

In Plat 8 where the corn was grown with beans, the legume increased the amount of dry matter, as well as the percentage of nitrogen. The yield of corn was almost double that on Plat 7.

In Plat 9, which was adjacent to and separated by four inches of soil, the legume increased the dry matter about 50 percent although the percentage of nitrogen was about the same as it was in Plat 7. This increase

in dry weight may be accounted for by diffusion of some nitrogenous material through the soil.

Nitrogen in Greenhouse Soil.

Samples of soil from all the plats were taken and analyzed.

Plat	1	had	0.22	percent	nitrogen.
"	2	"	0.22	"	"
"	3	"	0.21	"	"
"	4	"	0.23	"	"
"	5	"	0.24	"	"
"	6	"	0.24	"	"

The difference is not sufficient to account for any variation in the percentage of protein in the grass samples. Nitrate determinations were made also, but the plats had approximately the same amount present.

Field Results.

In the spring of 1912 we duplicated the experiments with corn and beans in the greenhouse on a small plat in the field. Beans were planted in alternate rows with corn. Wherever beans were planted in the same row with corn, the yield of corn was decreased.

Corn alone gave greater yields by 30 percent than where corn and beans were grown on the same plat.

We believed that the decreased yield produced in the field was due to the beans taking away from the corn the moisture as well as the plant food in the soil. Hence, the decreased yield.

Summary and Conclusions.

The moisture content of the soils of the greenhouse plats was always sufficient to produce conditions ideal for nitrification, and, as the soil contained sufficient nitrogen, these factors account for the high protein content of the blue-grass and timothy.

A sample of soil analyzed by the Station from a field that had remained in blue-grass for over fifty years had 0.4 percent nitrogen. This high percentage of nitrogen may be accounted for by its accumulation by the legume. Clover is always present, and the old plants die each year, leaving large amounts of organic nitrogen to become nitrified throughout the grazing months. This would indicate that the association of white clover with blue-grass on the grazing lands of Virginia may be indirectly responsible for the high protein content of blue-grass.

The question of whether a legume benefits a non-legume under field conditions is still an open one. We believe that the soil moisture and nitrogen factors exert more influence than could be derived from the association of a legume with a non-legume. This is borne out by the results obtained with corn and beans in the field.

Whenever plants, be they legume or non-legume, have to occupy the same area in the field and are crowded, one plant necessarily must steal some of the moisture and plant food that should go to the development of the other plant.

With blue-grass and white clover grown in the greenhouse no direct benefit was shown by their association, or being adjacent. With timothy and red clover no increase of protein was shown by their association during the first year. However, on Plat 5 in 1913 and 1914 some benefit was shown, which might be accounted for by turning under a previous crop of clover.

When corn and beans were grown in the greenhouse the corn was benefited by the association and the adjacent plant derived some benefit.

The results prove that immature plants have higher percentages of protein than the more mature ones.

NOTES ON PLANT DISEASES IN VIRGINIA OBSERVED IN 1913 AND 1914.[1]

By HOWARD S. REED AND C. H. CRABILL.

Alfalfa.

VIOLET ROOT ROT *(Rhizoctonia medicaginis)*.—Alfalfa plants were sent in from Daleville, Botetourt County, with the report that many such plants were dying in patches all over a two-year-old field. Examination showed them to be infected with *Rhizoctonia medicaginis,* which causes rotting of the root. The roots were covered with a thick mat of violet mycelium which also invested the outer layers of the bark.

Myriads of almost black, minute clumps of this mycelium apparently of a sclerotial nature dotted the surface of the bark. The purple color of the root extended upward to the surface of the ground and downward seven inches or more. How much more we cannot say, because the roots were cut off at this depth. The bark separated readily from the diseased roots.

YELLOW TOP.—This disease of alfalfa came into prominent notice in the season of 1914 when the climatic conditions were not favorable for plant growth over a large part of the State. The first cutting of the crop usually escapes, but the successive cuttings may suffer more or less severely especially in unfavorable seasons. Young alfalfa plantations suffer worse as a rule than those which have attained an age of three or more years.

Affected plants may be identified by the pale yellow color of the apical leaves, which in time becomes general on the leaves of the upper part of the plant. In distinction from the leaf spot caused by *Pseudopeziza medicaginis,* these yellow leaves do not fall, but remain firmly attached to the plants. There is often a pronounced purple color on diseased plants, which becomes more or less general when such plants are cut and cured for hay. The affected plants usually grow poorly and a continuance of the disease is fatal. The disease is undoubtedly identical with that described by Stewart, *et al.,* in New York.[2]

The following observations have been made in preliminary study of the disease in this State:

(1) Yellow Top presents none of the common symptoms of parasitic infection. It appears simultaneously over extended areas in the fields. Unless yellowing is due to the insects mentioned later, the disease does not begin at one place and spread to contiguous areas.

[1]Paper No. 35 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agr. Exp. Sta.
[2]N. Y. Agr. Exp. Sta. Bul. 305. 1908.

(2) The disease is worst in dry summers. Fields on the uplands suffer more than those on lowlands. Where rain was plentiful, there was comparatively little disease. The last cutting of the season was usually free from the disease because it received the benefit of the autumn rains.

(3) The disease is not due to a lack of lime. At the Experiment Farm at Staunton more yellow top was found on plats receiving four tons of lime per acre than on plots receiving two tons, because the former were on the most elevated part of the field.

(4) In the Eastern part of the State, yellow top was found in many places associated with girdling of the stems close to the ground by Tree-Hoppers (Membracids). This injury usually began adjacent to grass land and gradually spread from there.

Fig. 1.—White spot of alfalfa.

(5) In a few places, the yellow plants were found in the depressions in the fields. In such places it appeared that the plants had been started to active growth by the accumulation of the run-off following brief showers. The quantity of water thus afforded was only sufficient to start increased

growth without being able to support it for long. After the supply was exhausted the plants were worse off than before, and the yellow condition developed.

It is probably true that a variety of causes may be responsible for yellow top, and that many unfavorable factors may cause injury which is shown in this way.

White Spot.—This is a trouble due to an undetermined cause. Although the losses from this disease are small, it occurs in many sections of the State. White, semi-translucent, usually rectangular spots occur on the leaves, principally on the distal portions. (Fig. 1.) Affected plants usually show the white spots on nearly every leaf while adjacent plants may be entirely healthy. This trouble is most noticeable early in the season.

Anthracnose *(Colletotrichum trifolii)*.—At Williamsburg, James City County, many alfalfa plants were found diseased with a Colletotrichum, probably *C. trifolii* Bain & Essary. The lesions which occurred on the stems were oval to obovate and had a slight furry appearance. Occasionally such spots were confluent and caused the stems to fall over at that point, due to girdling.

Apple.

Blister Canker *(Nummularia discreta)*.—This disease, also known as Illinois apple canker, has reached Virginia. Its depredations have not yet

Fig. 2.—Grimes apple tree killed by collar blight. The canker is two years old and has completely girdled the tree.

been of serious proportions but reports and specimens have come in from Loudoun, Orange, Frederick and Montgomery counties.

Collar Blight *(Bacillus amylovorus)*.—Collar blight is plainly a form of fire blight caused by *Bacillus amylovorus*. It occurs in all the important apple growing sections of Virginia and is especially destructive in the Shenandoah Valley, where it works havoc on Grimes and Ben Davis. Occasionally even York Imperial is killed by collar blight. Most of the other varieties common in Virginia suffer but little. Some seem to be entirely immune. Losses in Ben Davis and Grimes orchards have been relatively enormous when we take into account the fact that a ten- or a twenty-year-old tree may be killed outright in a single season. About three years, however, are usually required to kill a large tree.

Fig. 3.—York Imperial apple tree affected with collar blight. This canker has spread slowly. The bark is completely dry and is sloughing off at the centre of the wound.

The collar blight usually starts on the east or northeast side of the trunk just above the soil surface. From there it spreads upward and outward, sometimes rapidly, sometimes slowly, but almost surely with fatal results. Never have the writers seen a tree which had recovered from collar

blight, although in many cases precautions were taken to prevent the spread of the parasite. Collar blight may be identified with certainty by the slightly depressed, discolored bark which has a decidedly sour, fermented odor when freshly cut.

The fact that the collar blight nearly always starts on the east or northeast side of the tree leads to the presumption that weather conditions in winter have a bearing upon the conditions necessary for infection. Cracks in the bark are probably inoculated by insects which have recently visited "hold-over" cankers from which the bacteria are oozing.

It is seldom that the orchardist notices collar blight until the evidence of its presence is manifested by the death or poor condition of the top of the tree unless he makes a special examination of all his tree trunks in the spring.

Attempts have been made by some orchardists to check collar blight by cutting away infected bark and painting the wounds. So far as we know, little success has attended these attempts. In all cases observed by the writers the blight continued to spread. Further experiments with disinfectants may ultimately yield results of practical value. Since blighted water sprouts may convey the organisms to the tree trunks, a prompt removal of the water sprouts is advisable.

At present all measures must be sanitary and preventive. The removal of all blighted wood from orchards as soon as it can be discovered is highly important. More necessary still in many cases is the removal of pear trees in or near the apple orchard. Instances are on record where the removal of adjacent pear trees had almost completely done away with both collar blight and twig blight in apple orchards. Pear trees, which are very susceptible to blight, constitute a source of infective material and are a menace to nearby orchards.

Crown Gall *(Bacterium tumefaciens)*.—In many sections of Virginia crown gall is a serious disease especially in nursery stock. Even in old orchards it causes great losses. Most of the old trees which are now dying, however, were infected when set. They are, for the most part, from fifteen to twenty years old. They have made poor growth and are only half as large as healthy trees of the same age. Usually a tree infected with crown gall lives for 10 to 20 years and then dies rather suddenly.

Death results in nearly all cases from a decay of the gall itself, followed by a decay of the root system and trunk. Such trees usually succumb during the winter. Many put forth in spring a weak covering of small leaves and flowers which soon wither away. This slight attempt at growth is made on food materials stored up in the twigs and branches, since in many cases the tree is completely dead at the base.

A few trees, however, die while the gall is still alive. In the majority of such cases the gall is on only one side of the tree and that dies first. Apparently the fibrovascular bundles are destroyed or so altered or contorted by the gall tumor that the transpiration stream is interfered with and all the wood above, which should be supplied by this stream, dies. With one side of the tree killed by crown gall it is only a matter of a short time until the whole tree is involved. If the crown gall itself does not cause the ultimate death of the tree, saprophytic fungi or wound parasities soon do so by destroying the whole root system.

FLAP TUMOR.—In two separate instances, one at Blacksburg and one at Hollins, Virginia, we have found tumors of a peculiar and interesting character on apple limbs. Lacking a designation, these growths have been called " flap tumors " on account of their shape.

The tree at Blacksburg, of variety unknown, exhibited an almost incredible number of these tumors in all stages of development. Accompanying them were a few typical aerial crown gall lesions. The largest and most

Fig. 4.—Flap tumors on an apple limb.

decidedly characteristic flap tumors occurred on the upper sides of branches three or four inches in diameter. (Fig. 4.) They may be described as shell-shaped flaps of hard, solid, apparently healthy wood, growing out from and extending partly around the branch that bears them. Fig. 5 shows one of these flap tumors in cross section. Enough of the annual rings have been included in the sketch to show that from one side of what is apparently a wound or disease lesion a rolling flap of wood has been put out, extending itself annually by addition of new wood and bark to the outer surface and to the margin. Some of the oldest flap tumors examined showed their age to be more than fifteen years. A blackened wound, surrounded by dense, hard, woody tissue, extends from the base of the flap downward

sometimes to the pith of the limb as shown in the sketch. Younger ones in all stages of growth were distributed over limbs and twigs, even out to wood only two or three years old.

A superficial examination shows that there are all gradations between young flap tumors and young crown gall lesions. The former appear to arise in nearly all cases from partly healed wounds apparently identical with cankered snowy Tree Cricket wounds. The latter arise as smooth pinkish tubercles under the bark which finally break through and become black and warty. The crown gall lesions may or may not have a blackened core,

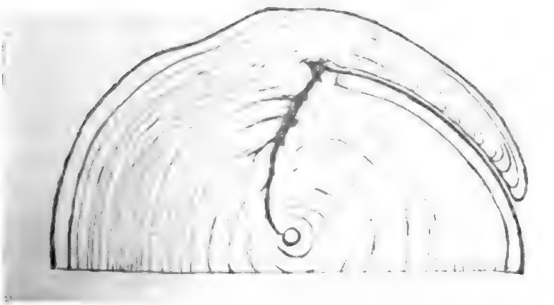


Fig. 5.—Flap tumor in cross section.

but typical flap tumors always have such a core. In the intermediate stages of development it is difficult to distinguish the one from the other. Some specimens cannot be classified certainly with the most careful study. In reactions to hot saturated bichromate of potash solution and to stains the elements of flap tumors and crown gall lesions are the same.

Whether flap tumors are due entirely to the growth of healing tissue in an attempt to close old cankered Tree Cricket wounds or whether the crown gall organism has a hand in the trouble it is difficult to say. The similarity of the two types of tumors in the intermediate stages and their unlikeness in the initial and final stages are confusing. Those tumors which arise as mere elevations under the bark soon becoming black and warty, are undoubtedly true crown gall. It is probable that some of the other tumors arising from Tree Cricket injuries finally become warty and black, thus forming what on the surface look like typical aerial crown gall lesions, and which beneath have the blackened core noted above, while others develop the flaps of wood already mentioned.

A complication of agencies may act to bring about the flap tumors. Tree Cricket injuries, according to Parrott and Fulton[1] often are cankered by a fungus—probably *Leptosphaeria coniothyrium,* causing a disk of bark to

[1] N. Y. Agr. Exp. Sta. Bul. 388. 1914.

peel off exposing a partially healed wound beneath. The illustrations of such wounds given by these writers agree closely with our specimens showing the initial stages of flap tumor or rather the type of injury from which the flap tumors arise. It is possible that such a wound may become a harbor for the crown gall organism if it is present in the tree and either a warty lesion or a flap tumor may be consequently developed, depending upon the relative vigor of the host and the parasite at that point. Perhaps the stimulus given when the tumor is in its initial stages starts the growth of the flap, which like any other part of the tree then continues to grow even after the causative organism has died out in that particular region.

Punky Pulp of Ben Davis.—This disease, noticed only in 1914, is characterized by small punky or corky lumps interspersed throughout the pulp of the Ben Davis apple. In addition, the fruits are smaller than normal, punky and brittle, and have a tendency to be divided into longitudinal sectors somewhat like a cantaloupe. The lenticels are very prominent. The fruit is tasteless and entirely unfit for consumption.

This trouble is due to dry weather. It was confined to excessively dry soils in the regions of the State most affected by the drouth.

Root Rot.—Root rot is at the present time one of the least controllable of all apple diseases in Virginia and is also one of the most destructive, even to growers who practice orthodox methods of sanitation and management.

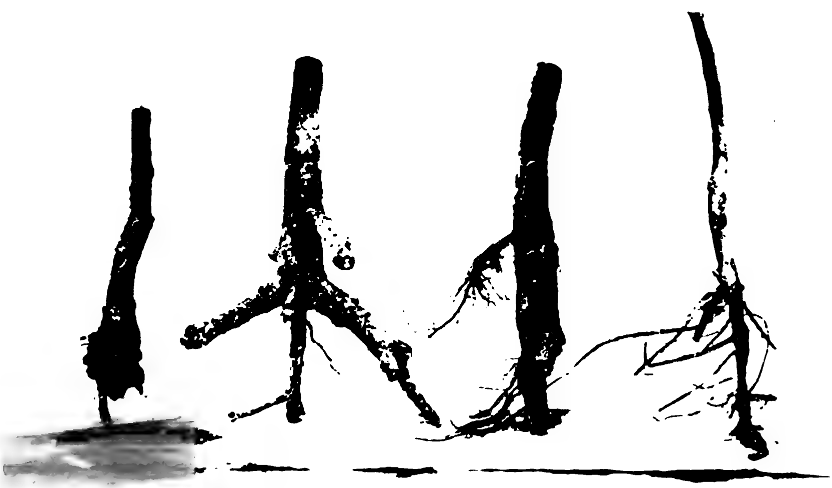


Fig. 6.—Stumps of young apples which have been planted in ground where former trees had been killed by root rot.

Trees affected with this disease may die at any age but the greatest numbers lost are from 10 to 15 years of age. Many trees come to maturity in ap-

parently perfect health, but die suddenly from this trouble as soon as they begin to bear fruit. The orchardist thus loses his ten or more years of labor and expense as well as the tree. Further than this, if another tree be planted where the dead one was removed the chances are about two to one that it will die also. In many orchards replants have died of the root rot within two years after being set and from 30 percent to 60 percent died before they were eight years old. (Fig. 6.)

Fig 7.—Apple tree affected with root rot. The unthrifty condition of the top is an indication of approaching death.

The first indication of the disease is a cessation of growth followed by a loss of some of the foliage, then by the death of a portion of the top of the tree. (Fig. 7.) An examination of the root then reveals a deplorable condition. All of the roots, except one or two on the live side of the tree, will

be dead, punky and brittle and filled with the fine white mycelium of a fungus. The tree can be readily pushed over in nearly every case. The roots break off short near the stump. Usually the disease begins on the roots situated deepest in the soil, and works upward. The deep lying roots are often completely destroyed while the more superficial roots are still sustaining the tree. Eventually, however, all the roots are killed and decay. Often

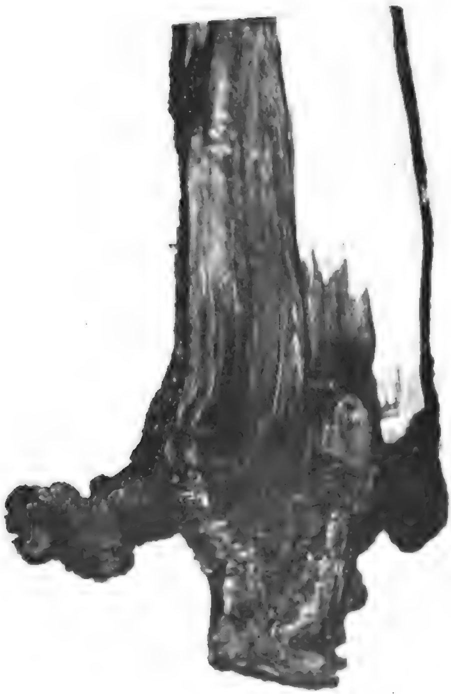


Fig. 8.—Longitudinal section of the stump of an apple tree killed by root rot.

one side of a tree becomes affected long before the other does, especially if the root system is divided into two or more divergent portions. The wood above the killed root dies first, becomes shrunken, and brown. The outer bark becomes checked with cracks and peels off in thin scales, the juncture between dead and healthy bark is sharply defined, often marked by a deep crack which extends to the sapwood, and the branches and twigs above all die and shrivel. (See Fig. 8). One-half of a tree may thus be completely dead while the other remains for a time quite healthy. The death of the upper parts of the diseased half is no doubt due to the cutting off of the

water supply from the soil. Sometimes, however, the mycelium of the fungus, which is always present in the root of root rot trees and which is presumably the cause of the trouble, is found in the wood of the trunk for some distance above the ground. This is especially true on wet soils. The symptoms of root rot do not usually become manifest until death is close at hand.

Our observations and reports from orchardists have brought to light the following important facts: (1) Root rot is more prevalent on new ground than on ground which has been cultivated for some years before the orchard was set, especially where the soil contains partially decaying wood, stumps, etc. (2) Root rot is present on high gravelly and low loamy soils alike. (3) The white mycelium of a fungus is a constant accompaniment of the disease. (4) In many orchards several adjoining trees in a group contract the disease at about the same time. Sometimes eight or ten trees will die around the first to succumb. (5) In Virginia, York Imperial is most susceptible to the disease, Ben Davis, Stayman Winesap, Black Twig and many others suffer occasionally.

No sporophores of the fungus found in rotted roots have been encountered, although they have been sought for assiduously. Black rhizomorphs similar to those ordinarily produced by *Armillaria mellea* have once been found. There seems to be little doubt, however, that the white mycelium found in rotted roots is the ultimate cause of the death of the tree. It may be a wound parasite following aphis injury, crown gall, borers, barking by implements of cultivation, etc., but as to this, no definite statement may be made at the present time.

Further studies on this disease are under way.

Skin Crack of the York Imperial.—This disease is, so far as observation goes, confined to the York Imperial. In some orchards as much as 50 percent of the fruit is affected. 10 percent to 30 percent of injured fruit is common. Until the summer of 1914, this trouble has been noticed only very rarely in dry seasons.

The following observations have been made upon the disease: Early in September, tiny sunken cracks appear in the skin of the fruit, each crack surrounded by a narrow red-brown margin. Most of the cracks are less than 2 mm. long and extend latitudinally. Some, however, are larger and extend in other directions. The fruit looks as if it had grown too fast for its skin, which was stretched to bursting. There may be many or few of these tiny cracks, usually many. Often a large number of these become continuous by spreading and give a grayish scabby appearance to that portion of skin. The skin crack is confined almost entirely to the shaded side of the fruit and is worse on the shaded portion of the tree. The red cheeks

of the fruits which are exposed directly to the sun's rays are free from cracks.

The season of 1914 was marked by a drouth from May 6 until August 1 over nearly all of the State. The Northern part of the Shenandoah Valley which had no rain until the middle of August suffered worst. It was in these drouth-affected localities that the skin crack was prevalent. In more favored regions it was absent. Even in Northern Virginia trees on low ground where an appreciable amount of moisture was present in the soil bore perfect fruit, while on trees on high ground, especially where the soil was gravelly, the fruit was badly affected. The trouble was found chiefly on the fruit of trees less than fifteen years old. In the vicinity of Middle-

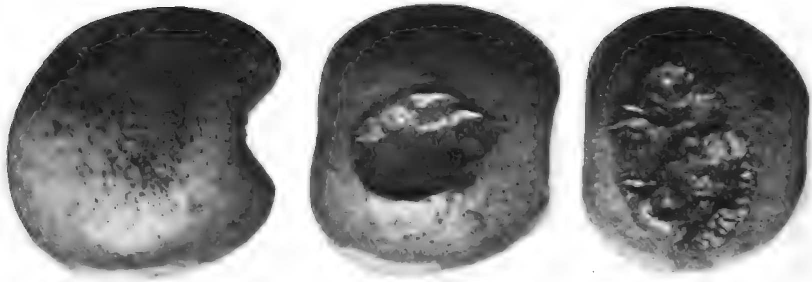


Fig. 9.—Skin crack of York Imperial apple and the typical rot which may follow it.

town, Virginia, in the centre of the drouth-affected area the apples grew but poorly and remained very small until the drouth broke in August. The fruits then increased remarkably in size in a very short time. By September 1 the skin crack was evident in the York Imperial orchards.

Zschokke[1] has pointed out that lenticels on the apple arise by a stretching and splitting of stomata due to the rapid growth of the young fruit. It does not seem impossible that the skin on the shaded side of the fruit may be actually stretched to bursting by the unusually rapid multiplication and growth of pulp cells due to sudden increase in the water supply. This, indeed, appears to be the nature of the injury. Microtome sections of skin crack show that the rupture of the epidermis stimulates a reaction in the cells of the hypodermal parenchyma beneath. By rapid division these cells build up a barricade of cork which protects the underlying pulp. (Fig 10.) Drying is perhaps the stimulus which results in the formation of the cork

[1]Zschokke, A. Ueber den Bau der Haut und die Ursachen der verschiedenen Haltbarkeit unserer Kernobstfruchte. Landw. Jahrb. der Schweiz. 11:153. 1897.

layer. In a few cases sections show that fungi have penetrated the cracks before a protecting layer of cork was formed. Mycelium is more or less abundant in the degenerating cells immediately beneath the crack and no cork layer is produced.

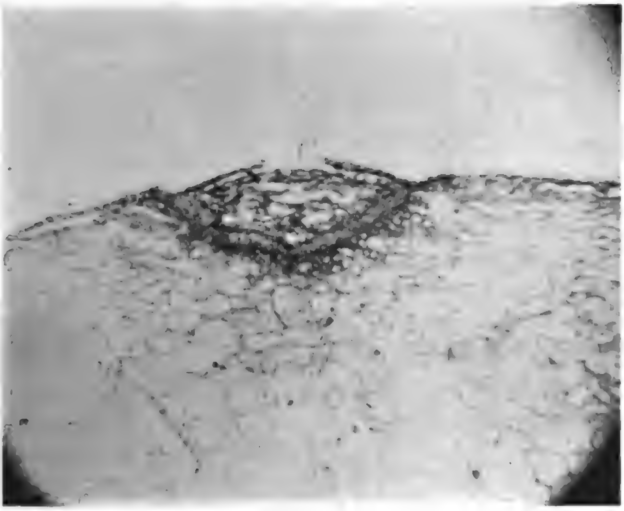


Fig. 10.—Section of skin crack showing the cork barricade which partially heals it.

The evidence seems to indicate that this disease is physiological, due to sudden increase in water supply. Careful inoculations from the tissue beneath the cracks and microscopic examinations show that in the initial stages no organisms are present. Sprayed and unsprayed fruits are affected alike. Fruits slightly or moderately affected with skin crack have been held in cellar storage for several months. Although there was considerable loss of water and consequent shrivelling of the cracked sides of the fruits, no rot whatever has developed.

A soft black rot caused by *Alternaria mali* Robts. is the almost constant attendant of the later stages of bad cases of skin crack. Such rot first appeared about September 10. Out of twenty inoculations from many typically affected fruits, twenty pure cultures of *A. mali* were obtained. It is evident that in some cases rot fungi may enter the skin crack as soon as it is formed, kill the pulp cells beneath, prevent the formation of a protecting cork layer and produce rot. Whether the cork layer can always protect the fruit from invasion of fungi is doubtful and it is likely that much of the Alternaria infection takes place through the cork some time after the epidermis has been ruptured.

Fig. 9 shows one apple with skin crack and two with the Alternaria rot which follows.

THE YORK SPOT.—Large losses have been sustained from the York Spot. even in well sprayed and well cared for orchards, especially during the season of 1914. In its early stages the York Spot is apparently identical with the Jonathan or Baldwin fruit spot, which is common on Jonathan, Baldwin, and Black Twig, and is occasionally found on Grimes and several other varieties. The typical Jonathan or Baldwin spot in Virginia is confined to corky pits, just beneath the skin of the fruit, seldom greater than 5 mm. in diameter. Ordinarily the actual injury to the fruit is small, although the appearance of the fruit hurts its marketability. The spots seldom spread or decay in cold storage. Occasionally the skin over a corky pit dies and gives entrance to decomposing organisms which ultimately destroy the whole fruit.

On the York Imperial such is not the case. The disease first makes its appearance in August as slightly sunken dark-green spots. At this stage the tissue immediately beneath the skin is much greener and denser than that surrounding and is tightly attached to the skin. Beneath this hard green disk is a roundish mass of brown corky tissue, the cells of which are brown-walled, hard to tease apart and very rich in starch. This form of

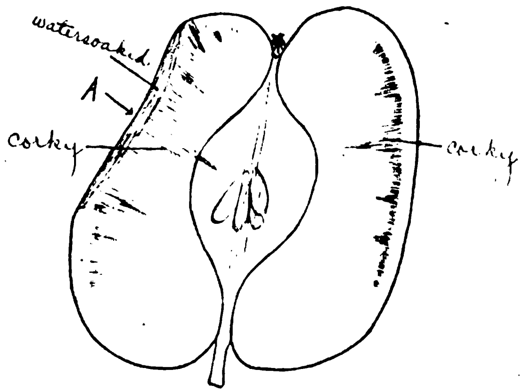


Fig. 11.—Diagramatic section of a York Imperial apple in advanced stage of the York Spot.

the York Spot looks very much like hail injury. No mycelium has been found in this tissue. Nearly a hundred inoculations have been made by thrusting bits of this tissue, cut out with a sterile knife, into suitable culture media. No organisms whatever grew from the spots.

Stained microtome sections show that in the corky tissue beneath the skin many of the cell walls have disintegrated, forming relatively large cavities in the tissue. No mycelium is apparent.

Up to this time the York Spot is apparently identical with the Jonathan or Baldwin fruit spot. As the season advances, about September 1, the corky condition begins to spread, extending itself under the skin about 2 mm. from the surface and around the apple latitudinally faster than longitudinally. The affected area becomes much depressed and takes on a characteristic water-soaked appearance. It is soft to the touch and becomes brown in color. The cells which give the water-soaked appearance lie just beneath the skin and outside of the corky layer. (Fig. 11.) Although they appear to be full of water, the reverse is probably the case. Lack of water and consequent partial collapse of the cells perhaps accounts for this appearance. The pathological condition of these cells is probably due to the destruction, or obstruction of the vascular bundles with consequent cutting off of the water supply. The evidence which seems to support this idea is (1) the corky condition of affected tissue spreads principally along the outermost portions of the vascular network and follows coreward the larger branches of the vascular system. (2) When a bit of the water-soaked tissue is teased up in water its cells imbibe freely, swell extensively and then under the microscope exhibit the appearance of typical healthy cells. This water-soaked tissue is apparently free from fungi.

Still later in the season (about September 20) the badly affected fruits show a soft rot in the depressed areas. The depression becomes more pronounced, the skin dies and turns brown and the rot progresses rapidly coreward. The tissue is full of fungus mycelium. This soft rot is no doubt due to infection by saprophytic fungi which takes place through the weakened or broken skin. *Alternaria mali* is easily isolated from the rotten spots. Fruits usually fall soon after this soft rot sets in.

The fact that no organisms have been grown from the York Spot until the soft rot sets in points to the conclusion that the trouble is at first physiological, subsequent infection by Alternaria being responible for the rot.

In some cases only a few affected fruits can be found on a tree. Usually, however, a very large percentage of the fruit on one tree will be rendered worthless by this disease while an adjoining tree may have an almost perfect crop. The disease is no worse on weak trees than on thrifty ones. It has been found most abundantly on the fruit of young trees or on older trees which had a small crop of fruit.

Sometimes the apples are stunted when numerous spots occur on a single fruit. Others with few spots will become full sized only to be destroyed during September. Deformed fruits are common.

What effect the wetness or dryness of the season, the exposure, the soil type, or methods of cultivation have, remain to be studied. Spraying does not seem to decrease the trouble. It is as bad in well sprayed orchards as in neglected ones.

SUNBURN.—The very hot weather during 1914 resulted in much sunburn on apple fruits. Those fruits which were exposed directly to the sun's rays for a greater part of the day were often injured. A browning of the epidermis resulted. Occasionally apples sunburned around the stem end fell off. Usually though, the injury was entirely superficial and the pulp under the skin sound. The light-brown color of the sunburned skin looks somewhat like a soft rot and hurts the salability of the fruit. Sunburn was more prevalent on Ben Davis than on other varieties.

Bean.

CROWN GALL *(Bacterium tumefaciens)*.—Snap beans have been found badly diseased with crown gall as shown in Fig. 12.

Fig. 12.—Crown galls on a bean plant.

Maple.

THROMBOTIC DISEASE OF SILVER MAPLE.—This disease was first noticed in Frederick County in 1913, and was prevalent the following year all along the Valley Pike where silver maples are used for shade and ornament. Residents state that the trouble has been present for a number of years. Many

trees are in very bad physiological condition and some will apparently soon die as a result of attacks of this disease.

The symptoms are quite distinctive and are manifested most strikingly on the foliage. The effects of the disease are apparent as soon as the leaves unfold in spring. The leaves are yellow with a sickly appearance, growth is poor and in advanced cases nearby limbs are dead or moribund. In some cases the leaves remain yellow throughout the summer and drop in the fall

Fig 13.—Maple leaves showing the characteristic symptoms of the thrombotic disease.

somewhat earlier than those on healthy trees. Usually however, the tips die, turn brown and curl up. The leaf droops. The dying of tissue begins at the tips of the leaves and spreads toward the petiole. Usually when about half the leaf tissue has browned and curled up the leaf falls (Fig. 13). Sometimes the tips of normally green leaves die, but usually yellowing precedes the death of the tissue. The fibro-vascular bundles in affected leaves become very dark.

In dry weather the disease appears to spread slowly. In rainy weather the leaves wilt rapidly and fall in great numbers. The disease takes on the appearance of an epidemic at such times. The belief therefore arose that this was a fungus or bacterial disease, affecting the leaves and spreading

rapidly by new infections in wet weather. It was therefore known as leaf blight.

In 1913 many trees were almost defoliated by September 1. Fig. 14 shows a tree almost destitute of leaves following a rain on July 29, 1914. Trees defoliated in summer often put out new clusters of leaves on twig tips

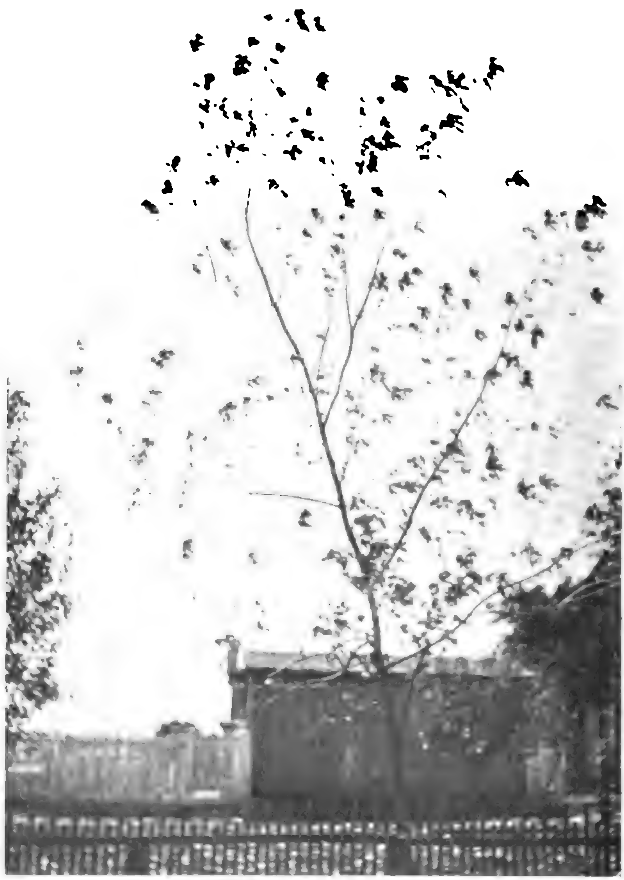


Fig. 14.—A silver maple on July 29, almost defoliated by thromobotic disease.

late in September. The loss of leaves and warm weather cause the next year's buds to push out into activity.

It was noticed in many cases that only a portion of a tree manifested symptoms of the disease while the remainder was healthy, and that one tree might be almost dead while another adjoining it was entirely normal. This led to an investigation of the affected limbs. The wood of such limbs was

found to contain dark streaks which became bright green in contact with air. (Fig. 15.)

At a recent meeting of the American Phytopathological Society Rankin[1] described and exhibited specimens of a maple disease producing similar

Fig. 15.—Sections of silver maple limbs showing the green strands characteristic of the thromobotic disease. In the upper left cross section the disease has just started.

green streaks in the wood. He had isolated a species of Acrostalagmus from such streaks and by inoculation reproduced the disease. He called this trouble thrombotic disease for the reason that the vasculars are plugged by the fungus, thus cutting off the transpiration stream.

Peach.

Peach Scab *(Cladosporium carpophilum)*.—In the spring of 1914 peach trees were severely injured by the scab fungus. Many trees suffered the loss of 85 percent of their twigs, which were killed back a foot to two feet from the tips, and much pruning was required for their removal.

A large part of the fruiting wood was killed. Young orchards not yet in bearing and older ones which bore no fruit on account of late frosts have been most damaged, probably because they received no summer sprays.

[1]Phytopathology. 4:395. 1914.

In the summer of 1914 some preliminary spraying experiments were carried on at Blacksburg for the control of this disease. The results obtained show that the disease on the twigs may be prevented by spraying with self-boiled lime-sulphur at intervals of fifteen to twenty days from July 1 to September 1.

Plum (Wild Goose).

PHRAGMIDIUM SUBCORTICICUM.—Plum twigs sent in from Chesterfield County were much hypertrophied and distorted.

Potato.

POTATO RHIZOCTONIA.—This disease has been collected in potato fields near Norfolk and on the Eastern shore of Virginia. From one to five percent of tubers were affected. Black sclerotial masses of the sterile fungus are found on the skin of the potato. The fungus is superficial and the injury to the tuber practically none.

The great injury done by this disease occurs at planting time. If infected tubers are used for seed or infected soil is used for planting, the fungus spreads to the young sprouts, which may be quickly killed. A second crop of sprouts may likewise be destroyed. Irish Cobbler is one of the most seriously affected varieties.

TIP BURN.—Potato tip burn has been attributed to strong arsenical spray material, to drouth, and to other causes. In the drouth affected localities of Virginia, tip burn has been very prevalent. The injury to the potato crop in the Shenandoah Valley in 1914 was relatively large. Early plantings of potatoes grew only about six inches high, browned and died without producing a crop. In sections of the State where rain was sufficient, tip burn was not so abundant.

Tip burn begins at the tips and edges of the leaf, progressing gradually inward. The leaf turns brown and rolls up as fast as the disease progresses. The browned tissue is brittle, readily breaks off, and is marked with fine lines parallel to the advancing zone. It is easily and often confused with the common late blight caused by *Phytophthora infestans.*

Contrasting tip burn with Phytophthora blight, the former always begins at the edge of the leaf and advances inward, producing dead, brittle, dark brown, rolled margins. The latter begins anywhere on the leaf, producing target marked, grayish-brown spots.

WILT *(Fusarium oxysporum).*—On potato plots at Blacksburg the wilt was quite abundant in 1914. It killed outright the vines of certain varieties,

Fig. 16.—Potato vines killed by wilt, (Fusarium oxysporum).

while others were affected but little. The list below shows the varieties noted and the prevalence of wilt on each, on July 23:

Irish Cobbler	None
Early Rose	"
Carman No. 3	"
Moneymaker	Slight
Peerless	"
Gold Coin	"
Spalding's Rose No. 4	"
Earliest	Pronounced
Beauty of Hebron	"
Extra Early Sunlight	"
Burbank	Bad
Green Mountain	"

Sir Walter Raleigh	Bad
Carman No. 1	"
Bliss' Triumph	All dead

HOLLOW HEART.—Examination of tubers of several varieties of potatoes at and prior to digging time in 1914, showed that a large number of the tubers were hollow at the center. This condition prevailed principally in regions where drouth was severe during the first part of the summer and rain plentiful the latter part of the season. The presence of this condition cannot be detected without cutting the tubers open. Aside from the cavity in the center they are healthy and normal in every respect. They have no tendency to rot in storage and the flesh adjacent to the hollow has no disagreeable odor or taste when cooked.

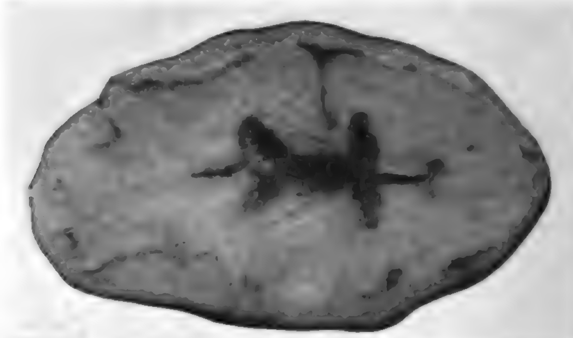


Fig. 17.—Hollow heart of potato. One longitudinal crack with two or more lateral ones is typical of this disease.

Hollow heart is attributable to drouth followed by abundant rain in the later part of the growing season. The peculiar shape of the cavities is well shown in Fig. 17.

Scale Parasite.

(Sphaerostilbe coccophila.)—Professor Schoene and Mr. Price of the Office of the State Entomologist collected at Abingdon and other points in Southwest Virginia, apple limbs infected with San José scale, which had been parasitised by *Sphaerostilbe coccophila.* All of the insects had been killed and one or more of the red conidiophore bundles of the fungus protruded from under the armor of each. Pure cultures were obtained and studied. The economic value of this fungus as a scale destroyer is probably small in most localities, but at the high altitude of Southwest Virginia with its heavy precipitation and its dewy summer nights it appears to be a common and efficient scale parasite.

FOUR PAPERS ON

NITROGEN FIXATION AND NITRIFICATION IN VARIOUS SOIL TYPES.

By HOWARD S. REED AND BRUCE WILLIAMS.

(1)—The Effect of Mineral Fertilizers on Nitrogen Fixation and Nitrification in the Soil.[1]

The bacterial flora of soils which have received prolonged and definite applications of mineral fertilizers has been the subject of rather meager attention. The status of bacterial activities as regard inorganic substances is imperfectly understood and, while a subject of considerable interest, it is justifiably relegated to a secondary place in soil bacteriology investigations. Yet to note the bacterial activities of any soil which has received "control" treatment is eminently worth while since some condition may be observed which exerts an unmistakable influence. This paper reports a study of nitrification and nitrogen fixation on soils that had received annual applications of fertilizers for five years.

Through the courtesy of Prof. T. C. Johnson an opportunity was afforded in 1913 to study the soils of some of the experiment plats of the Virginia Truck Experiment Station. The soil samples were taken from twentieth acre plats which had grown various truck crops, none, however, which should have exerted a peculiar influence on the bacterial flora. The samples were carefully taken and immediately brought to the laboratory. The fixation tests were made by incubating ten grams of soil in 100 c. c. Ashby's solution for 21 days and making total nitrogen determinations for the increase. For nitrification tests, 400 grams of soil in Erlenmeyer flasks was incubated with 1 percent ammonium sulphate for six weeks, at the end of which period nitrate determinations were made by the Iron-Zinc Reduction method.

Tables I and II give the results of these tests. Under the column " Annual Fertilizer Treatment " is given the amount of fertilizer the soils received annually per acre for five years. The laboratory numbers are the same for both tables.

[1]Paper 36 from the Laboratories of Plant Patholoilgy and Bacteriology, Virginia Agr. Exp. Sta.

TABLE I.—*Nitrogen Fixation Tests.*

Lab. No. Soil Sample	Annual Fertilizer Treatment	Mgs. of N. per 100 c. c. Ashby's Solution with 10 grams soil		
		At Beginning	After 21 Days	Ave. Increase
1	Control; no fertilizer	8.1 9.3	18.48 18.94	10.01
2	Crimson clover turned under	11.2 10.9	19.88 18.34	8.6
3	Crimson clover turned under 1500 pounds Hydrated Lime	8.26	21.21	10.6
4	15 T. stable manure Acid (Rock) phosphate, (16 percent available phosphoric acid), 2000 pounds 1 year; 1000 pounds 4 years	8.6	21.84 22.12	13.48
5	Same as 4 with 1500 pounds Hydrated Lime additional	7.28	22.76	15.48
6	Acid (Rock) phosphate, (16 percent available phosphoric acid), 2000 pounds 1 year; 4000 pounds 4 years	7.7 8.5	17.74	9.62
7	Kainit, (12 percent actual potash), 1000 pounds	8.5 9.1	21.56	10.7
8	Cotton Seed Meal, (7 percent nitrogen, 2 percent phosphoric acid. 2 percent potash), 4000 pounds	8.4 8.6	21.3	10.8
9	Peruvian Guano, (4 percent nitrogen, 2 percent phosphoric acid, 4 percent potash), 2000 pounds	7. 7.5	17.31	10.6
10	Nitrogen, (4 percent $NaNO_3$) Potash, (8 percent KCIC), 1000 pounds	6. 6.5	20.16	13.9
11	Phosphoric Acid, (8 percent), KCIC (8 percent); 1000 pounds	6.3	15.47	9.17

TABLE II.—*Nitrification Tests.*

Lab. No.	Mgs. of N. Nitrogen per 100 gms. dry soil	
	At beginning	After six weeks
1	.9	4.42
2	1.74	8.12
3	....	27.7
4	....	9.74
5	....	22.52
6	....	6.44
7	....	7.01
8	2.2	4.73
9	2.0	6.96
10	....	2.28
11	....	2.74

Reviewing Table I, we note the failure of the various inorganic fertilizers to offer any marked stimulation to nitrogen fixation. The soils all have a rather high nitrogen fixing power, yet the control plat which received no fertilizer has an Azotobacter flora which is excelled in only one or two cases. The maximum fixations are attained under the influence of stable manure, and that with lime records the highest increase in nitrogen noted in the series. The minimum fixation, that from soil No. 2 which had crimson clover turned under without lime, is not unexpected. The acid condition resulting from such a practice would undoubtedly account for this decrease. The high fixing power of soil No. 10 is difficult to explain. It does not appear probable that nitrate of soda should induce any special development of Azotobacter. If so, it is significant that less nitrogen in this form was more conducive to their growth than were larger quantities of organic nitrogen. The action here suggests a parallel to the benefit which leguminous crops are supposed to derive from light dressings of nitrate of soda during the early stages of growth.

The Azotobacter films on all of the soils were uniformly good and those on soils Nos. 3, 4, and 5, were the richest ever observed in this laboratory.

The nitrification tests are assertive in at least one point, namely, the conspicuous results obtained by the use of lime. From Table II it will be seen that crimson clover increased the nitrifying power of the soil 83 percent while crimson clover and lime produced an increase of 526 percent. The use of stable manure likewise increased nitrification 120 percent and the addition of lime here produced a 407 percent increase. The combination of crimson clover and lime was more efficient in promoting nitrification than was stable manure and lime. The remaining soils except Nos. 10 and 11 gave uniformly higher nitrifying power than the control plat, yet it is questionable that any combination of fertilizers was responsible for this. Their use probably induced general fertility, which stimulated nitrification somewhat, yet no striking result is noted—certainly none commensurate with that produced by lime, for example.

(2)—Studies on Nitrogen Fixation in Various Soil Types [1]

The process of nitrogen fixation of Azotobacter has been definitely established; it is probably of widespread activity; its importance is of disputed magnitude, regarded as paramount in soil fertility by a sanguine few, but held in abeyance by a significant number of others. Despite the investigation which the problem has received, no very definite conclusions can be drawn. The unexpected fixation by one soil, the near failure of another, possessing the qualities usually ascribed to soils of high fixation power, are obstacles to the investigator who would dogmatically assert the conditions

[1]Paper 37 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agr. Exp. Sta.

upon which fixation depends. Depreciate as one may the importance of Azotobacter as a significant source of nitrogen, the striking quantity of that element in virgin soils, its accumulation in fallow lands, its partial maintenance in cultivated fields can be accounted for by no more plausible theory than by attributing it to the activities of the above mentioned organism—to this or to anaerobic bacteria possessing similar faculties for fixation.

The present paper deals principally with comparative fixation in virgin and cultivated soils of the same type, and with the process as affected by soils of widely different texture. It notes also the quantities of nitrogen in virgin and cultivated soils that have been collected from various sections of the State and the relationship, if any exists, between the original nitrogen content and the increase by fixation.[1]

Virginia is a State of wide variety in its soil types. It presents many gradations from the heavy red clay of the Piedmont section to the fine sandy loam of Tidewater Virginia. The Bureau of Soils of the U. S. Department of Agriculture has surveyed twelve widely different sections of the State and classified the soil types therein. It was on the basis of this classification that the soils used in the present work were collected. A few were obtained outside of the surveyed area yet these were characteristic in their texture. Many soils of the same name and type but from widely separated areas were collected that various sections as well as soil types might be represented. In practically every case two samples of each type were collected, one uncultivated and the other under cultivation at the present time. The term "virgin" might be properly applied to the uncultivated series, for in the majority of cases they have never received cultivation and all have lain idle for a number of years.

An agent from the station in many cases did the collecting, and, when this was not the case, instructions were sent to the various county demonstrators, who kindly coöperated in the work. About two gallons of soil were obtained for each sample and shipped to the station by express. As soon as they arrived, the soils were screened and placed in covered tin pails especially constructed for the purpose, and from these composite samples were obtained for the various tests. Soils number 1-55 were collected between May 13 and November 25, 1913, and those from 56-93 were collected between April 10 and July 26, 1914. In every case the tests were made immediately after the soils were brought to the laboratory.

FIXATION TESTS.

The fixation tests were carried on in solution. Whether or not this method is representative of field conditions, it is the only satisfactory one we

[1]This work was planned and started by Dr. E. B. Fred, formerly bacteriologist in this Experiment Station, before his removal to the University of Wisconsin. The authors wish also to acknowledge their indebtedness to Professor R. J. Holden for suggestions regarding the geology of soil types in this State.

have found for measuring fixation. Some preliminary tests were made at the beginning of the work, using plates with 400 grams of soil to which were added 4 grams of mannite and kept at 28° C. for 21 days. But the fixation by this method was so slight that it gave no index to the comparative power of the soils to fix nitrogen. The method finally used employed 100 c. c. of Ashby's solution in 1 litre Erlenmeyer flasks to which were added 10 grams of soil. The Ashby's solution was made according to the following formula:

Mannite	20	grams
$NaCl$	.2	"
$Mg\ SO_4$	.2	"
$Ca\ SO_4$	.1	"
$K\ H_2PO_4$	.2	"
Water	1000	c. c.

The mono-potassium phosphate was dissolved separately and neutralized with NaOH.

Four 10 gram portions from each soil were weighed out on a dry basis. Two of the Erlenmeyer flasks, containing 100 c. c. of solution, each received 10 grams and the remaining portions were analyzed for total nitrogen by the Kjeldahl method. The flasks were incubated for 21 days at approximately 28° C. at the end of which time their entire content was analyzed for total nitrogen by the method previously employed. The average from the two analyses was taken. There was always close agreement in the two results from the soil itself and seldom any wide variations in the fixation flasks. Where this did occur, the tests were repeated. The slight variations which always accompany fixation tests are impossible to avoid. In Table I is given the soil type as classified by the Bureau of Soils, the original nitrogen content of the virgin and cultivated soils, and the increase in each after 21 days incubation of 10 grams in 100 c. c. of Ashby's solution. The first of the two numbers refers to the virgin soil.

TABLE I.—*The Fixation of Nitrogen by Various Soil Types in Ashby's Medium.*

No. Soil Sample	Soil Type	Mgs. N. Originally present per 10 gms. soil		Increase in mgs. per 10 gms. soil after 21 days with 100 c. c. Media			
		Virgin	Cultivated	Virgin	Cultivated	Virgin Per ct. Increase	Cultivated Per ct. Increase
1-2	Hagerstown Silt Loam	13.8	12.6	2.95	3.5	14	28
3	" " (Rich)	13.8	14.35	2.95	4.55	14	31
4-5	" Stony "	9.31	20.86	2.38	10.76	25	52
6	Hudson River Shale (Meadow)	....	27.4	....	3.5	..	12
7-8	DeKalb Silt Loam	14	20.72	1.82	3.22	13	11
9-10	" Stony "	15.26	10.11	3.22	8.47	21	84
11-12	" Silt "	17.5	16.1	3.68	4.6	21	28
13-14	Hagerstown Silt Loam	15.82	21.97	12.18	14.08	76	64
15-16	" " "	10.7	16.3	8.2	14.4	76	88
17-18	" " "	12.3	8.6	10.16	16.7	82	193
19-20	Cacapon Sandstone	21.4	21	6.39	5	29	23
21-22	Devonian Shale	11.4	14.28	13.6	16.7	118	110
23	" " (Flood Plain)	14.7	....	4.7	....	32	..
24-25	Clay Loam	28	15.58	10.7	14.84	38	95
26-27	Sandy Loam	3.7	4.9	7.1	13.22	190	270
28-29	Cecil Clay	8	7.8	14.9	5.1	186	65
30-31	Clay Loam	9.6	8.3	13.39	12.5	140	150
32-33	Iredell Clay	16.8	10.6	4.58	2.18	27	20
34-35	Cecil Loam	13.28	9.38	6.36	8.17	47	86
36	" " (Meadow)	....	10.05	....	15.15	..	140
37-38	Loudon Sandy Loam	10.49	6	5.51	7.34	52	90
39-40	Cecil Clay	11.6	8.1	5.19	3.84	44	47
41-42	" Loam	9.6	13.7	12.31	17.3	128	125
43-44	" Sandy Loam	7.6	3.9	.5.23	18.8	68	480
45-46	Iredell Clay Loam	11.6	7.9	2.3	3.6	18	45
47-48	Sandy Loam	6.4	4.62	5.77	4.53	90	98
49-50	Clay Loam	5.5	7	3.65	4.76	66	66
51-52	Norfolk Sandy Loam	6.5	1.3	11.45	8.6	175	661
53-54	Leonardtown Loam	6.4	6.4	6.37	7.43	99	113
55	Swamp	16	....	12.8	....	79	..
56-57	Black Clay	21.26	25.48	12.46	10.34	58	40
58-59	Norfolk Sandy Loam	9.52	4.18	2.21	8.8	23	210
60-61	Leonardtown Loam	8.8	6.7	3.56	15.48	40	229
62-63	Sandy Loam	4.8	5.4	11.3	10.6	235	196
64-65	Cecil Clay	6.7	5.5	14.31	10.27	213	194
66-67	" Sand	9.78	3.8	6.7	16.45	67	432
68-69	Iredell Clay	8.82	7.56	6.98	6.35	78	84
70-71	Cecil Clay	19.04	5.57	8.8	7.1	46	127
72-73	Fine Sandy Loam	6.72	4.62	7.11	8.1	105	175
74-75	Cecil Sand	3.25	3.6	5.41	5.32	166	148
76-77	Hagerstown Loam	10.5	11.9	6.3	7.84	60	65
78-79	Clay Loam	13.5	12.6	8.72	8.6	64	68
80-81	Cecil Clay	9.6	10.5	7.9	5.49	82	52
82-83	Hagerstown Clay	8.6	9.5	5.6	4.9	65	51
84-85	" Loam	25.8	16.1	8.6	5.3	33	32
86-87	" Sandy Loam	12.3	9.5	7.84	5.69	63	59
88-89	" " "	11.3	9.6	4.29	5.82	37	60
90-91	Edgewater Stony Loam	8.8	5.6	5.18	5.4	58	98
92-93	Sandy Loam	3.6	5.7	7.2	7.7	200	135

By referring to Table I it will be seen that there were 93 soils examined and of these 88 were in pairs, that is, consisting of a virgin and cultivated sample. From these 44 pairs, 26 gave a higher fixation by the cultivated and in 18 the virgin soil excelled in the addition of nitrogen. The average increase where the cultivated soils were highest was 3.98 mgs. and where the virgin samples excelled the average gain was 2.08 mgs. The total nitrogen fixed by the virgin samples was 331.66 mgs., and that fixed by the cultivated samples was 389.74 mgs., or a total increase of 58 mgs. Table II summarizes these several points:

TABLE II.—*Giving the Comparative Results of Nitrogen Fixation by 44 Virgin and 44 Cultivated Soils.*

Number of Pairs in which Cultivated Soils excelled	26	
Number of Pairs in which Virgin Soils excelled	18	
Average Increase where Cultivated Soil excelled	3.98	mgs.
Average Increase where Virgin Soil excelled	2.08	"
Total Nitrogen fixed by Cultivated Soils	389.74	"
Total Nitrogen fixed by Virgin Soils	331.66	"
Original Nitrogen in Cultivated Soils	455.25	"
Original Nitrogen in Virgin Soils	513.38	"

The superiority of cultivated soils in fixing nitrogen is strongly indicated by results from the foregoing table. They are in accord with the recent findings of Greaves[1] though not so pronounced, due perhaps to very dissimilar conditions. A substantial majority of the soils examined showed a higher fixing power by the cultivated samples than by the virgin, and the increase where noted in cultivated soils was relatively much higher than when it took place in the virgin soils. These results are without regard to any factor save that of cultivation and for this reason are all the more significant. They represent tests from a large number of soils of varying texture, collected from definitely separated areas, and the cultivated samples had experienced a variety of types of cultivation. Notwithstanding these facts the evidence which points to the advantages of cultivation in developing the Azotobacter flora is unmistakable. This would seem at least one indubitable stimulation which free nitrogen fixation may receive.

An interesting point is the higher original nitrogen content of the virgin soils as compared with the cultivated ones. The analyses of 44 virgin samples showed that in 29 of that number there was more total nitrogen than in the corresponding cultivated samples, and of the 18 virgin samples which excelled the corresponding cultivated ones in fixation, 15 had also more total nitrogen. Yet it is difficult to trace from the foregoing results any relationship between the amount of nitrogen in a soil and that which it adds by

[1]Greaves, J. E. A study of bacterial activities in virgin and cultivated soils. Cent. f. Bakt. II. Abt. Bd. 41., p. 444.

fixation. It is probable that under field conditions, as Koch and Seydel[1] have shown, the removal of nitrogen by crops is necessary to further fixation. The results obtained from the above tests do not indicate that the presence of nitrogen is of material influence on fixation.

As previously stated an effort was made to observe the influence of soil texture on fixation. It would be interesting to note the intensity of the development of the Azotobacter flora in soils of widely different types and to investigate the marked differences where they do appear. The widespread occurrence of Azotobacter is not suggestive of its susceptibility to difference in soil types. Von Feilizen, however, has reported the very slight occurrence of Azotobacter in peat[2] and moor[3] soils, even after long periods of cultivation, and, though probably without much justification, the idea has grown up that fixation is more marked in soils of light open texture than in the heavier soils. Since cultivation obviously affects the process and the cultivated soils considered in this paper received cultivation varying widely in kind and intensity, it would be illogical to compare results from them as evidence in support of fixation by any special type. It is only, therefore, the virgin samples which are considered in this relationship. A general classification of five different types was found to include all of the 44 virgin samples, and, while the number of soils was not the same in every classification, an average of the nitrogen fixed by each class would reveal any noteworthy difference between them. In Table III is given the soils with their numbers which were thus classified and the average in milligrams of nitrogen which each type fixed.

TABLE III.—*Average Nitrogen Fixed by a Number of Virgin Soils of Various Texture.*

Soil sample numbers	Classification	Average in Milligrams of Nitrogen fixed
51, 53, 58, 60, 66, 72, 74 (7)	Fine Sandy Loam	6.11
19, 26, 47, 62, 86, 88, 92 (7)	Sandy Loam	7.12
1, 3, 4, 7, 9, 11, 13, 15, 17, 34, 37, 41, 43, 76, 84, 90 (16)	Loam	5.7
24, 30, 45, 49, 78 (5)	Clay Loam	7.75
21, 23, 28, 32, 39, 56, 64, 68, 70, 80, 82 (11)	Clay	8.99

The comparison would perhaps be more fair if the number of soils in each type were the same, but since the average is taken it seems justifiable to report on all the soils. Collected as the soils were with reference only to soil type and having received no treatment whatever, the results have a considerable degree of interest. The nitrogen fixing flora has presumably

[1]Koch and Seydel. Cent. f. Bakt. Abt. II, Bd. 31. 1911. p. 570.
[2]Feilitzen von H., Svenska Mosskulturfor. Tdskr. 25, 1911, No. 1, pp. 53-57.
[3]Feilitzen von H., Fuhling's Landw. Ztg. 59. 1910. No. 14, pp. 489-492.

been influenced by no factors other than the natural inorganic status of the soil, its humus content, and its physical condition. To be sure, the two first named factors may be of controlling importance—we are inclined to believe the supply of humus is an all important one in comparison with which the others are relatively insignificant. The only difference in the above figures which would warrant conclusions is that between the clay soils and those of lighter texture. And that fixation in these heavy soils should exceed that of the lighter ones is not without its element of surprise, yet the difference is quite well defined—even the clay loam exceeds the loams and the sandy loams in fixing nitrogen.

Rather than asserting the superiority of clay soils or of any special soil type in fixing nitrogen, the results summarized in Table III more poignantly demonstrate the indifference with which that process is affected by such factors. This fact has been impressively presented in many instances in the present study.

By singling out from Table I the results from a few cultivated soils regardless of their origin and noting their power of fixation, it is difficult to ascribe any influence whatever to soil types. Such examples are presented in Table IV.

TABLE IV.—*Nitrogen Fixation by a Number of Cultivated Soils of Various Types.*

No.	Soil Types	Milligrams Nitrogen fixed per 100 c. c. Media with 10 gms. soil
52	Norfolk Fine Sandy Loam	8.6
27	Sandy Loam	13.22
85	Hagerstown Loam	8.6
31	Clay Loam	12.5
65	Cecil Clay	10.27
55	Swamp	12.8

Under proper cultivation and a sufficient supply of humus—disregarding for the moment certain other factors—it appears that the type of a soil would have negligible influence on its power for free nitrogen fixation.

SUMMARIZING DISCUSSION.

The examination of ninety-three soils, eighty-eight of which were collected in pairs of virgin and cultivated samples, showed clearly the superiority of cultivated soils for nitrogen fixation. Though some of the virgin samples excelled in the addition of nitrogen, the average increase, where induced by cultivated soils, was appreciably higher than where it resulted from virgin soils. Tables I and II summarize these results.

Fixation by the virgin samples was noted also with regard to soil type, since a number of samples of widely different character were examined. The results from a number of virgin soils of the same type were averaged and compared with averages from other soil types. The average from the clay soils was highest, showing quite a perceptible increase over the lighter soils. But on account of results in fixation tests with cultivated soils, the writers hesitate to ascribe any marked influence to soil texture and regard it as a rather immaterial factor. Many cultivated soils, regardless of type, showed notable nitrogen fixing power. In Tables II and IV are to be seen summaries of these points.

In connection with results obtained in the present work, the reports of previous investigators along this line are of interest. A reference to the work of Greaves, in which he found higher nitrogen fixing power of virgin than of cultivated soils, has been previously made in this article. A notable amount of work on factors which influence fixation has concerned itself with the alkalinity[1] and phosphate[2] content of soils. The concensus of these reports emphasize the importance of lime in fixation. That phosphates are essential to the proper development of Azotobacter has been amply demonstrated by laboratory tests, but it is questionable whether they are ever a limiting factor under field conditions. Some fixation tests at this station on soils which had received various combinations of mineral fertilizer for five years fail to disclose any results that might be attributed to inorganic causes.

The general indications from fixation studies which the authors have carried on are that—with the possible exception of lime—the humus content of a soil and its cultivation are the only factors which materially affect fixation. It would seem that with these properly adjusted the process could always reach its maximum efficiency—cultivation to promote æration and removal of nitrogen, and humus to supply the energy essential to the activities of the nitrogen fixing flora.

(3)—Studies on Nitrification in Various Soil Types.[3]

The accumulation of so great a number and variety of soils afforded an unusual opportunity for observing the process of nitrification. To study it contemporaneously with fixation was of no little interest for it is probable that each is affected by many of the same factors.

---

[1]Ashby, S. F. Jour. Agr. Sci. 2. 1907. No. 1, pp. 31-51.
Christensen, H. R. Cent. f. Bakt. II Abt. 17, 1906, Nos. 3, 4., pp. 109-119. Figs. 2, 5, 7, pp. 161-165; Figs. 2, 11-13. pp. 378-383.
Fisher, H. Journal f. Landw. Bd. 53, 1905. p. 290.
Gerlach und Vogel. Cent. f. Bakt. Abt. II. Bd. 9, 1902. p. 891.
Hoffman and Hammer. Cent. f. Bakt. Abt. II, Bd. 28, 1910., pp. 127-139.
Lipman, J. G. Ann. Rept., N. J. Exp. Sta. Bul. No. 206, 1907. p. 4.
Mockeridge, F. A. Ann. Bot., London, Vol. 26, 1912. No. 113., pp. 871-897.

[2]Gerlach und Vogel. Cent. f. Bakt. Abt. II., Bd. 10, 1903. p. 638.
Hoffman, C. Cent. f. Bakt. Abt. II., Bd. 36. pp. 474-477.
Lipman, J. G. Ann. Rept., N. J. Exp. Sta., Bul. 29, 1908. p. 139.

[3]Paper 38 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agr. Exp. Sta.

The soils used in the experiments, and their manner of collection, have all been set forth in the preceding paper. Suffice it to say that the soils retain the same number throughout these reports and the nitrification tests were made from the same sample and simultaneous with those which measured fixation.

It was decided that soil itself should be the medium in which nitrification would be measured, and the "nitrifying efficiency" method as proposed by Stevens and Wither[1] was adopted and used throughout the series of tests. The soil was first carefully sieved and then 400 grams weighed on a dry basis was placed in one litre Erlenmeyer flasks. To this was added 10 c. c. of sterile ammonium sulphate solution containing 240 milligrams nitrogen and the soil brought to 18 percent moisture content. Two flasks were set up for each soil and were kept in the incubator room at approximately 28° C. for six weeks, the moisture content being kept at 18 percent. At the end of this time nitrate determinations were made, usually by the Iron-Zinc Reduction method, or in cases where the nitrate content was low, the phenol-disulphonic acid method was employed. The results are reported on the basis of milligrams of nitrate nitrogen per 100 grams of soil.

All of the soils were subjected to another series of tests which may be termed "nitrate accumulation." Four hundred grams of soil were weighed out as before, but now into ordinary quart fruit jars. These samples were kept in the incubator room for six months at 28° C. and 18 percent moisture content. No ammonium sulphate was added and the nitrate present in the soils at the end of six months reflected the power of the soils to convert their own organic nitrogen into nitrate. The analyses at the end of this period were made by the phenol-disulphonic acid method.

Determination of the original nitrate content was made for all soils immediately after they were brought to the laboratory. These analyses showed extremely small quantities of nitrates present in the soils and in many cases only a trace was to be found. Yet these quantities, however negligible, were deducted from the amount found at the conclusion of the tests and all the figures represent increases in nitrate over that originally present. In Table I the results from all nitrification tests are presented. As in the fixation tests, 93 soils were examined, 88 of which were in pairs of a virgin and cultivated sample. In the table is shown the nitrifying efficiency of the various soils with 60 milligrams nitrogen as ammonium sulphate per 100 grams of soil and the accumulation of nitrate by the soils when kept under optimum conditions for six months. The figures are the averages from two flasks for each soil. The blank spaces indicate no nitrate.

[1]Stevens and Withers. Studies in Soil Bacteriology. III. Cent. f. Bakt., Bd. 25, pp. 64-79. 1910.

TABLE I.—*The Nitrifying Efficiency of Various Soil Types With and Without Ammonium Sulphate.*

No. Soil Sample	Soil Type	Increase in mgs. Nitrate N. per 100 gms. soil with 60 mgs. $(NH_4)_2\ SO_4$ after 6 weeks		Accumulation of Nitrate Nitrogen per 100 gms. soil after 6 months	
		Virgin	Cultivated	Virgin	Cultivated
1-2	Hagerstown Silt Loam	14.54	8.36	No Analysis	No Analysis
3	" " "	....	7.2	" "	" "
4-5	" Stony "	3.44	14.5	4	8.3
6	Hudson River Shale (Garden)	....	46.76	....	6.2
7-8	DeKalb Silt Loam	3.7	7.24	4	5
9-10	" Stony "	9.15	5.24	3.7	1.44
11-12	" Silt "	2.24	9.24	4.24	6.16
13-14	Hagerstown Silt Loam	12.25	20.7	4.52	9.6
15-16	" " "	1	22.4	6.64	5.6
17-18	" " "	....	....	4.8	2.72
19-20	Cacapon Sandstone	2	21.93	3.2	7.6
21-22	Devonian Shale	....	19.58	1.92	2.6
23	" "	....	....	....	....
24-25	Clay Loam	45.78	46.69	....	....
26-27	Sandy Loam	3.26	9.12	....	....
28-29	Cecil Clay	11.8	25.11	....	....
30-31	Clay Loam	5.5	40.39	1.8	.14
32-33	Iredell Clay	5.58	1.54	8.06	4.6
34-35	Cecil Loam	14.44	3.24	6.9	7.4
36	Cecil Loam (Meadow)	....	13.38	8.06	....
37-38	Loudon Sandy Loam	3.3	5.1	9.6	4.4
39-40	Cecil Clay	10.8	5.62	9.6	8
41-42	" Loam	15.27	29.6	3.6	6.8
43-44	" Sandy Loam	3	7.28	1.46	1.46
45-46	Iredell Clay Loam	7.42	3.36	2.4	2.2
47-48	Sandy Loam	.56	1.19	3.2	2.4
49-50	Clay Loam	....	6.5	1.2	2.6
51-52	Norfolk Sandy Loam	....	....	2.4	1.2
53-54	Leonardtown Loam	....	.6	2	6.6
55	Swamp	1.8	....	10	....
56-57	Black Clay	11.6	14.47	12	9.4
58-59	Norfolk Sandy Loam	3.78	2.1	1.6	1.6
60-61	Leonardtown Loam	14.86	4.69	6	6.4
62-63	Sandy Loam	....	1.42	1.44	8.4
64-65	Cecil Clay	....	13.3	1	2.2
66-67	Cecil Sand	2.7	1.5	9	4
68-69	Iredell Clay	1.88	1.86	5.2	6.6
70-71	Cecil Clay	1.58	1.58	13.6	7.6
72-73	Fine Sandy Loam	3.4	....	6.6	4.8
74-75	Cecil Sand	....	1.32	....	4.4
76-77	Hagerstown Loam	5.8	30.41	10	9
78-79	Clay Loam	43.34	30.74	10	12
80-81	Cecil Clay	4.4	15.4	2.2	3
82-83	Hagerstown Clay	14.08	1.6	4.4	4
84-85	" Loam	46.9	21.9	4.2	12
86-87	" Sandy Loam	11.87	11.2	10	10
88-89	" " "	5.7	17.74	10	8.4
90-91	Edgewater Stony Loam	.6	2.4	4.8	3.8
92-93	Sandy Loam	....	2.8	1.4	2.6

Considering first the influence which cultivation exerts on the nitrifying power of soils to which ammonium sulphate has been added, evidence is presented which shows that of the 44 pairs of virgin and cultivated samples, 27 gave higher nitrate formation by the cultivated soil; in 15 the virgin sample excelled; and in two there were no nitrates formed by either member of the pair. Comparing the total amount of nitrates formed by the two series, the cultivated soils show again a superiority over the virgin samples, and the average increase, when taking place in the cultivated sample, was 9.43 mgs. as compared with 6.98 mgs. in the virgin sample. Table No. II is given to summarize these points.

TABLE II.—*Comparative Nitrifying Efficiency of 44 Virgin and 44 Cultivated Soils after Six Weeks.*

Number of pairs in which cultivated soils excelled	27	
Number of pairs in which virgin soils excelled	15	
Number of pairs in which no nitrification took place	2	
Total increase in nitrates by cultivated soils	489.27	mgs.
Total increase in nitrates by virgin soils	347.00	"
Average increase where cultivated soils excelled	9.43	"
Average increase where virgin soils excelled	6.98	"

The evidence which points to a more efficient nitrifying flora in cultivated soils than is present in corresponding virgin types is unmistakable. The process of cultivation undoubtedly tends to develop the nitrifying organisms chiefly, it may be supposed, through superior aeration which it affords. The relationship which is here brought out is very similar to that noted in the fixation tests, practically the same number of soils showing superiority of the cultivated samples. More significant still is the fact that the increases, when induced by the cultivated flora, average considerably higher than when resulting from the virgin flora which would indicate a higher degree of virulence of the bacteria which produced the respective processes as well as preponderance in occurence.

As was the case with the fixation tests an effort was made to trace a relationship between soil type and its influence on nitrification. Only the virgin soils were noted in this connection and the general classification of all the soils into five different types as previously made was used in the present instance. The nitrates formed by the virgin soils of these respective types were averaged and are presented in Table III.

TABLE III.—*Nitrifying Efficiency of a Number of Virgin Soils of Various Textures.*

Soil sample numbers	Classification	Average mgs. Nitrate Nitrogen per 100 gms soil
51, 53, 58, 60, 66, 72, 74 (7)	Fine Sandy Loam	3.46
19, 26, 47, 62, 86, 88, 92 (7)	Sandy Loam	3.18
1, 3, 4, 7, 9, 11, 13, 15, 17, 34, 37, 41, 43, 76, 84, 90 (16)	Loam	9.04
24, 30, 45, 49, 78 (5)	Clay Loam	20.5
21, 23, 28, 32, 39, 56, 64, 68, 70, 80, 82 (11)	Clay	5.61

There are some very striking differences to be noted in the foregoing table and, indeed, so noticeable are they that one might readily assume them to result in a large degree from soil texture. The results are from virgin soils, it will be recalled, and ammonium sulphate had been added to each sufficient to supply all the nitrogen necessary for conversion into nitrates. It would seem, therefore, that the nitrifiers were much less developed in certain soil types than in others. The open sandy soils are strikingly low, the loam and clay loam are as impressively high, and in the heavier clays again a falling off is evident. This latter decrease cannot be attributed to denitrification, since the control conditions of the experiment would scarcely admit this process. A condition which brought the averages of the sandy soils so low was due to some of the soils failing completely to nitrify and this was seldom true of the soils of heavier texture. Yet the failure of the former soils to produce nitrates was probably due to their lack of organic matter rather than to any inherent physical condition. The great majority of them are to be regarded as poor soils, low in humus, and deficient in those qualities which would develop a vigorous bacterial flora of any kind. Were these soils to be subjected to a well directed system of organic manuring they would, in all probability, as some of our own experiments indicate, assume a high place in nitrifying efficiency.

The heavy clay soils also are somewhat low in their nitrifying power. That aeration is essential to nitrification is too well demonstrated to question and these virgin clay soils had not the advantage of that condition to stimulate their nitrifying powers. The inhibiting effect of texture could likely be ameliorated by proper cultivation and there are indeed so many instances of this that it is probable that the undesirable condition may usually be overcome. Considering the natural powers of clay soils to nitrify, the results just cited show that, like extremely open sandy soils, the process is not so vigorous as in some of the other soil types.

The most satisfactory condition for nitrification, as exemplified by the results from this work, is that which is afforded by soils of the loam and clay

loam types. The averages from nitrification tests in these soils are considerably in advance of the others. The conspicuous increase in the clay loam, from a relatively small number of soils it is true, is one of the most striking results recorded. Apparently in soils of this type, carrying a fair amount of organic matter, a condition for maximum nitrification is obtained.

The gradation in the nitrifying power of these virgin soils is extremely interesting—the scant formation of nitrates in sandy soils, the pronounced increase in loams and clay loams, and the depression of nitrification in heavy clay soils are indeed noteworthy.

In considering the influence of soil types on nitrification it will be well to inquire first how far cultivation will go in obliterating the differences which previously have been discussed. By singling out from Table I a number of cultivated soils which show high nitrifying powers, one from each of the five general classes, some idea may be obtained of the possibilities which each soil type presents. Such figures are presented in Table No. IV.

TABLE IV.—*Giving the Nitrifying Efficiency of a Number of Cultivated Soils of Various Types.*

No.	Soil Type	Mgs. of Nitrate Nitrogen increase per 100 grams soil
67	Cecil Sand	1.5
44	Sandy Loam	7.28
42	Cecil Loam	29.5
31	Clay Loam	40.39
29	Cecil Clay	25.11

The figures in Table IV are maximum results from cultivated soils of the respective types. The sandy soils are yet notoriously low, the loams and clay loam are high, the clay soil has responded to cultivation and presents a high nitrifying power. Although the maximum figure for sandy soils is low in the present investigation, such has not always been our experience with these soils. A previous report of a Norfolk soil which for five years received crimson clover turned under as green manure and yearly application of lime, showed a formation of 27.7 mgs. nitrate nitrogen per 100 grams of soil. It is possible, therefore, to develop soils of that type to a high degree of nitrifying power.

Of course the above results are from isolated cases and are not worthy of general conclusions. They are given merely to illustrate the possibilities which most soils probably possess from the standpoint of nitrification as promoted by the proper type of cultivation.

The relationship which nitrification and nitrogen fixation bear to one another was observed with interest throughout the present investigation.

The processes are both important factors in soil fertility; they doubtless respond to many of the same agencies; the degree of their activity is certainly one index to the crop producing power of arable lands. It would be logical to expect, therefore, that soils showing high nitrifying powers would exhibit likewise unusual qualities for fixation. For the sake of comparison a number of cultivated soils with outstanding properties in either process were chosen that the two qualities might be noted with reference to the same soil. These comparative figures are presented in Table V.

TABLE V.—*Comparing Certain Cultivated Soils, as to their Nitrifying and Nitrogen Fixing Power.*[1]

No.	Increase in Nitrate Nitrogen Mgs per 100 gms. soil	Increase in total Nitrogen per 10 gms. soil per 100 c. c. Ashby's Medium
5	14.5	10.76
6	46.76	3.5
14	20.7	14.08
16	22.4	14.4
18	....	16.7 —
20	20.7	5 —
22	19.58	16.7
25	46.69	14.84
29	25.11	5.1 —
31	40.39	12.5
36	13.38	15.15
42	29.5	17.3
44	7.28	18.8 —
57	14.47	10.34
61	4.69	15.48—
63	1.42	10.6 —
65	13.3	10.27
67	1.5	16.45—
77	30.41	7.84—
79	30.74	8.6
81	15.4	5.49—
85	21.9	5.3 —
89	17.74	5.82—

The soils employed in Table V include all cultivated soils from Table I which produced as high as 13 mgs. nitrate per 100 grams soil and all those which fixed as high as 10 mgs. nitrogen per 10 grams soil in 100 c. c. Ashby's medium. The total number is 23 and of this number 11 showed nitrifying and fixation powers which may be regarded as commensurate one with the other. In the remaining 12 there is apparently no relationship between the two processes.

In the light of the above results there is no basis for assuming that nitrification and fixation are favored by the same influences; that they are

[1]The minus sign following a number indicates that the nitrifying and fixation powers of that soil do not appear to be correlated.

susceptible to similar agencies of depression or stimulation. Apparently the two processes have little in common, for in 50 percent of the soils exhibiting an unusual power in the one process that same soil showed peculiar indifference to the other. Yet despite these results the authors are reluctant to assume such a position. It is at variance with the principles which are believed to regulate both nitrification and nitrogen fixation. It would be safer to ascribe such contradictions as those above to untrustworthiness of method than to conclude that two processes so intricately connected with soil fertility are unrelated. Perhaps in the great majority of our present cultivated soils, receiving as they do no especial treatment which would tend to develop either process, that neither proceeds with such vigor as would present opportunities for noting a relationship between the two. But soils which are unusual in their fertility, which have been intensely cultivated with reference to promoting those processes which govern productivity—in the great majority of these we necessarily expect a vigorous nitrifying and nitrogen fixing flora which are closely related in their activities.

Referring once more to Table I the results from the nitrate accumulation tests are to be observed. These tests were made by keeping 400 grams of soil in glass fruit jars in the incubator room for six months at 28° C. and 18 percent moisture content. No nitrogen was added to the jars and the figures represent the conversion of original organic nitrogen into nitrates. Only one jar was set up for each soil. The results of these tests are summarized in Table VI in the manner of those in which ammonium sulphate was used.

TABLE VI.—*Giving the Comparative Accumulation of Nitrates in Certain Virgin and Cultivated Soils.*

Number of pairs in which cultivated soils excelled	19	
Number of pairs in which virgin soils excelled	19	
Number of pairs in which no nitrification took place	3	
Total increase in nitrates by cultivated soil	217.02	mgs.
Total increase in nitrates by virgin soil	202.68	"
Average increase where cultivated soils excelled	2.8	"
Average increase where virgin soils excelled	1.99	"

In two of the pairs of soil the nitrates were the same and in one the analysis was lost.

The distinction in the nitrifying power of virgin and cultivated soils is not present here to the degree noted in the foregoing tests. The number of pairs in which the virgin soil excelled is the same as where the cultivated soil was highest; the total quantity of nitrate formed is slightly more in the cultivated soils than in the virgin; and the average increase is somewhat higher when induced by the former than when taking place in virgin soils. This condition of equality in nitrifying power of the two types of soils is probably due to the superior quantities of nitrogen originally present in the

virgin soil—in 28 of the 44 pairs such was the case—and to the long period through which the tests ran allowing the slower action of the virgin soils to finally approach that of the cultivated ones. In 15 of the 19 pairs in which the virgin excelled the cultivated sample in nitrate accumulation, the organic nitrogen was higher in the virgin soil.

In yet another particular the present tests failed to confirm those with ammonium sulphate—in the accumulation of nitrates as regards soil type. On the basis of the classification previously used, averages from a number of soils of the same general type are given in Table VII.

TABLE VII.—*Nitrate Accumulation of a Number of Virgin Soils of Various Textures.*

Soils	Soil Type	Average increase mgs of Nitrate Nitrogen per 100 gms. soil after six months
(7)	Fine Sandy Loam	3.9
(7)	Sandy Loam	4.17
(14)	Loam	4.96
(5)	Clay Loam	3.06
(11)	Clays	5.07

The contradiction is in the case of the clay loams registering highest in nitrifying power with ammonium sulphate and lowest in nitrate accumulating power. The other results are in accord with those previously cited. It is difficult to explain such a discrepancy as this. Of course the validity of any comparison of the two series of tests is open to question—an inorganic nitrogen supply being used in the one case and an organic in the other, and the duration of the two experiments so widely different. Yet whatever correlation is obtained serves to strengthen the conclusions from each test. Nitrification at best is a process which is notorious for discrepancies even under ideal conditions for measuring it, and agreements which come about despite inequalities in methods are not unwelcome. The failure of clay loam to accumulate quantities of nitrate which correspond to their power of nitrifying ammonium sulphate belongs to that phase of nitrification which the authors would not attempt to explain.

Attention is to be called to the complete failure of certain soils to exhibit nitrification. In the tests with ammonium sulphate, 10 virgin and 4 cultivated soils exhibited this deficiency and 6 virgin and 5 cultivated soils failed to accumulate any nitrates through the conversion of their organic nitrogen. In Table I such soils are indicated by blanks in the columns containing the quantities of nitrates.

It is noteworthy that in most cases where the failure occurs it is true of both the virgin and cultivated soils of a pair. This quality of soils has often

been reported, notably by Stevens and Withers,[1] and is not infrequently met with in studies on nitrification. Where it occurred in the present study, it was a characteristic of extremely poor soils and it is probable that only in such soils is the condition ever to be found.

SUMMARIZING DISCUSSION.

The studies on nitrification of ninety-three Virginia soils revealed some interesting facts regarding that process. Cultivated soils showed decidedly higher nitrifying qualities than virgin soils. This fact was exemplified in that twenty-seven of forty-four pairs of virgin and cultivated samples, the latter exhibited superior nitrifying powers, the average excess of nitrates was higher in cultivated soils than in the virgin samples, and the total nitric nitrogen was considerably higher from the cultivated soils.

There appeared to be considerable difference in the nitrifying power of virgin soils of various texture. This quality in the light open sandy soils was strikingly low, in the loams and clay loam it reached its maximum height, and in the heavy clays there was again depression, yet not so low as in the extremely open soils. The high nitrifying power of certain cultivated soils irrespective of texture, suggests however that this power may be largely increased by proper cultivation. The deficiency of light soils is probably due to a lack of organic matter; the depression in the clay soils could doubtless be ameliorated by aeration from tillage.

From the results of this investigation it is unwarranted to conclude that soils with high nitrifying power would exhibit also unusual qualities for free nitrogen fixation or vice versa. In 50 percent of the soils which were notably superior in either process such a relationship could not be traced, but in the remaining 50 percent there was close agreement in the vigor of the two processes.

The soils were examined also for their accumulation of nitrates over a period of six months. There was not exhibited in these tests the distinctive nitrifying superiority of cultivated soils over virgin soils as was evinced in the tests with ammonium sulphate, due perhaps to the higher organic nitrogen content of the virgin soils and the longer duration of the experiment. The clay loam failed in these tests to show nitrifying powers commensurate with those they exhibited with ammonium sulphate, though the relationship as regarded other soil types was quite consistent in the two series of tests.

A number of soils evinced no power whatever to nitrify. Some soils which failed to nitrify ammonium sulphate in six weeks accumulated quite significant amounts of nitrate from their own organic nitrogen in six months. On the other hand there were some which nitrified the inorganic medium

[1]Stevens and Withers. Science. Vol. XXIX. No. 743, p. 506.

and failed to accumulate nitrates. There appeared to be no relationship between the ability of a soil to nitrify the two types of media.

The Effect of Sand and Lime on Nitrification.[1]

The stimulation which lime offers nitrification is universally accepted as one of the most far reaching effects which it exerts on soil fertility. This fact has been shown by so many experiments that it no longer provokes intelligent controversy. Furthermore one phase of the beneficial activity usually ascribed to lime is a physical influence which it exerts on soils and which renders them open and friable, more easily penetrated by air, conditions which presumably favor nitrification. It is to be expected, therefore, that, other conditions being equal, soils of light open texture would have a higher nitrifying power than compact heavy soils. Working with this idea in view, an effort has been made in a few instances[2] to promote nitrification in clay soils by the addition of sand in various proportions. Comparative experiments with sand and lime are of interest, since each contributes something to the process of nitrification as influenced by the physical condition of the soil.

During the summer of 1914 an experiment was carried on at this station duplicating somewhat the work previously reported but introducing one new feature—an observation on the effect of adding one-fourth clay to an open sandy soil. These soil types which have had extensive use here, were employed in the work: Albemarle and Appomattox Chocolate, both heavy clay soils, and Norfolk sandy loam, one of the light porous soils from Tidewater Virginia. The experiment was arranged in the greenhouse, using two gallon pots which received soil in the following order:

Albemarle Clay	Appomattox Chocolate Clay	Norfolk Sandy Loam
2 Controls	2 Controls	2 Controls
2 with one-fourth sand	2 with one-fourth sand	2 with one-fourth sand
2 with .15 percent $CaCO_3$	2 with .15 percent $CaCO_3$	2 with .15 percent $CaCO_3$
		2 with one-fourth clay

The same quantity of soil was added to each pot and all brought to 18 percent moisture content. That the rate of nitrification might be measured more strikingly, ammonium sulphate .1 percent was added to all pots. The experiment received the usual greenhouse care, the moisture content of the pots being kept uniform, and there was no condition which failed to influence all pots alike. At the end of the eight and twelve weeks, 500-gram samples were taken for nitrate analyses which were made according to the Iron-Zinc Reduction method. The results of the analyses from each pot are given in Table I.

[1]Paper 39 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agr. Exp. Sta.
[2]Reitmair: Zeitschr. f. d. Landw. Vers.—Wesen in Osterreich 11, 1908, p. 215.
Fred, E. B. Va. Agr. Exp. Sta. Ann. Rept., 1911-12, p. 185.

TABLE I.—*The Effect of Sand and Lime on Nitrification.*

Soil Types	Mgs. Nitrate N. per 100 gms. Soil: After 8 weeks	After 12 weeks
Norfolk Sandy Loam: Controls	8.7 8.02	20.8 20.8
" " " plus .15 percent $CaCO_3$	30.7	52.04 53.7
" " " " one-fourth Sand	4.1 6.8	14.83 13.07
" " " one-fourth Appomattox Choc.	9.4	20.84 20.66
Albemarle Clay: Controls	10.33 9.54	21.19 22.6
" " plus .15 percent $CaCO_3$	22.25	32.98 33.82
" " " one-fourth Sand	4.8 4.02	9.6 10.3
Appomattox Choc. Clay: Controls	15.5 16.3	29.48 35.92
" " " plus .15 percent $CaCO_3$	20.25 22.73	46.42 43.94
" " " " one-fourth Sand	11.89 12.91	23.32 24.5

A review of the foregoing table prominently asserts at least two facts—the enormous increase in nitrates under the influence of lime and the failure of sand to stimulate nitrate formation in clay soils. The actual depression of nitrification in the presence of sand which is true throughout the experiment is hardly to be expected. Such an influence would not unlikely be exerted on the Norfolk sandy loam, a soil which is well enough aerated in its natural condition, and the addition of sand would only dilute the organic matter present. Pure sea sand practically free from organic matter was used in the experiment and there was some loss in total organic matter wherever it was introduced. Yet this fact scarcely accounts for the falling off in nitrification, as nitrogen was abundantly supplied by the ammonium sulphate. In the control pots, which received no treatment whatever. nitrification proceeded more rapidly in the clay soils than in the Norfolk soil. On the other hand the use of lime was attended with uniformly better results with Norfolk soil than with the clays, and the maximum amount of nitrate found was in Norfolk soil with .15 percent $CaCO_3$ after twelve weeks. The more rapid formation of nitrates in heavy soils than in light open ones was reported as recently as 1911[1] and the notable response of Norfolk soil to lime has been often noted at this station. It would seem, therefore, that the action of lime in the present experiment is not to be attributed to any physical influence it exerted on the soil, and attempts to parallel such action—had it been achieved with lime—by the use of sand in clay soils were accompanied by an actual depression of nitrification. By

[1]Fischer, H. Landw. Jahrb. 41:755-822. 1911.

adding one-fourth percent clay to Norfolk soil there was practically no increase in nitrification, yet no deleterious action was noted such as that reported by Pichard.[1]

There are in the above analyses some slight variations in results from pots which received duplicate treatment. This is to be expected when such large quantities of nitrate are being measured. The differences between the pots which received different treatment are so well defined that it is easy to attribute it to the particular treatment each pot received. The variations emphasize, however, the fact that it is unwise to draw conclusions in nitrate tests on extremely small difference especially if large quantities of nitrates are involved.

The results in this paper are somewhat at variance with those published in the Annual Report of this Station, 1911-12[2] An increase in nitrification was noted therein under the influence of one-fourth sand when added to Albemarle and Appomattox chocolate soils, the former giving with sand a maximum increase over the control of 2.8 mgs. per 100 grams of soil and the latter 7.5 mgs. The experiment which showed these results was started in November, 1911, and no increase from the sand was observed until April of the following year. From that date until September the increase was observed. As the present experiment ran from May to August, 1914, the period of active nitrification was practically the same in both experiments. The variations can only be explained by the difference in time which the two experiments ran, yet admitting this factor the results on this point are somewhat irreconcilable.

[1]Compt. rend. (Paris), 109, 1889. pp. 455-447.
[2]P. 185.

THE EFFECT OF SOME ORGANIC SOIL CONSTITUENTS UPON NITROGEN FIXATION BY AZOTOBACTER.[1]

By Howard S. Reed and Bruce Williams

The influence which the organic constituents of the soil may exert on its productivity has been studied heretofore with reference mainly to the growth of higher plants. That deleterious substances of an organic nature exist in many soils and that they may exert a toxic action on plants growing in such soils, have been shown by previous work along this line. Investigations which have had as their controlling idea an inquiry into the nature of these compounds, derived as they are either from soil humus or from the excreta of growing plants, have presented some rather strong evidence in support of the toxic theory of soil infertility.[2] The nature of the results of these investigations would certainly warrant an extension of the research into other physiological fields.

The phase of study which would present the closest relationship to that already pursued and at the same time contribute something to the question of soil fertility, would concern itself with the bacterial flora of the soil. There is no more vital factor in the fertility of agricultural lands than those processes which are the result of microscopic plant life. The close relationship which has been shown to exist between these microscopic forms and the higher plants whose growth they so intimately affect, their response to the same agents of stimulation or depression, their close analogy in most physiological functions—these facts justify the conclusion that any abnormal condition affecting the one would have a corresponding effect on the other. If there are organic poisons in the soil which are toxic to growing plants, would not such fundamental processes as nitrification and nitrogen fixation reflect likewise the depression?

The theory which would account for the unproductiveness of soils by the presence in them of toxic substances assumes two possible sources of the inhibiting compounds—the vegetable or animal matter present in or applied to soils, and the excretions of growing plants. While, as previously noted, the effect of these organic poisons on the micro-organisms which influence soil fertility has been scarcely noted, yet bacteria, as a division of plant life,

[1]Paper No. 30 from the Laboratories of Plant Pathology and Bacteriology. Virginia Agricultural Experiment Station. Blacksburg, Va.

[2]In this connection the reader is referred to Schreiner and Reed, U. S. Dept. Agr. Bureau of Soils, Bulletins 40 and 47; Schreiner and Shorey, U. S. Dept. Agr. Bureau of Soils, Bulletin 53. The Duke of Bedford and Pickering, Reports Woburn Exp. Fruit Farm. 1900, 1903, 1904. Jour. Agr. Science. Vol. 6, (2), 1914, p. 136.

have received extensive study on account of the nature of their own excretions. In fact, it is in this connection that some of our most important principles of immunity have been evolved and with them complete triumph over a vast number of diseases. So well established is this fact, the knowledge that bacterial life produces substances poisonous to living forms of the same or related species, that it seems scarcely necessary to review the literature in this connection. It must not be assumed, however, that this fact proves that the excreta of soil bacteria are a factor in soil fertility, but it does lend credence to the theory that higher plants, during their process of growth, excrete substances which accumulate in the soil to the detriment of succeeding crops.

There are few biological processes in the soil which are of more scientific interest than those which help maintain the nitrogen supply through the means of non-symbiotic atmospheric fixation. Especially is this true of that aerobic group of organisms which were reported first by Beijerinck in 1901 and which are designated by the general term Azotobacter. Since their discovery, this phase of soil bacteriology has received careful attention at the hands of many investigators. The widespread occurrence of the organisms, the index which their presence and activity give to the fertility of a soil, are matters of interest. Only recently the authors noted an increase of 15 milligrams of nitrogen per 10 grams of soil incubated in Ashby's solution, and a pure culture of the organism from another source, cited subsequently in this paper, gave a similar fixation in the same medium. Should an approach to these results be made possible under field conditions, it would certainly exert a profound influence on the maintenance of soil nitrogen. The activity, in some sections, of Azotobacter in accumulating atmospheric nitrogen has resulted, it is alleged, in such concentration of nitrates as to render the soil toxic to plant growth.[1]

Indeed it is not unlikely, in the face of what is at present known of this organism's activity, that much of the organic nitrogen of soils must be referred to this and to related sources.

In regard to the possible effect of the organic constituents of the soil on the growth of Azotobacter, this group of organisms has shared the general inattention accorded most other soil bacteria. Their susceptibility to any kind of poisons has received only limited study. Experiments with carbon bisulfide,[2] doubtless induced by the recent theory of its antiseptic action on soils, found that substance fatal to Azotobacter in concentration of 1.7 to 1,000. More closely related to the present study is the work of Krzemeniewski on various humus bodies as affecting the development of Azotobacter.[3] The food requirements of the organism, its most economic utiliza-

[1]Wm. P. Headden. Colo. Agr. Exp. Sta. Bulletins 155, 160, 178.
[2]Maassen and Behn. Mitt K. Biol. Anst. Land.—u. Forstw., 1907, pp. 38-42.
[3]Krzemeniewski, S. Investigations on Azotobacter Chroococcum. Bull. Inter. Acad. Sci. Cracovie, Cl. Sci. Math. et Nat., 1908, pp. 929-1051. Av. 1 pl., Fig. 2: abs. in Zeitschr. f. Landw. Versuchsw. Osterr. 12, 1909, pp. 558-559. E. S. R., Vol. 22, 1910, p. 221.

tion of various carbohydrates, has been more thoroughly investigated. Ashby in 1907 gave the formula for the medium which bears his name and which is peculiarly adapted to the development of the organism. The superiority of mannite as a source of energy has been further demonstrated[1] as have many other factors which promote maximum efficiency in fixation. Among them are to be mentioned the requirements of the organisms as regards aeration; its response to certain inorganic compounds which appear to be controlling factors in its development—for example, phosphates and alkaline carbonates.[2] These are but examples of numerous studies along various phases to which Azotobacter have been subjected.

The growth of Azotobacter can be directly measured by the increase of nitrogen in the medium in which it grows. This property of the organism makes it ideally suited to study the effect of various compounds on its development. Any stimulation or depression which might result would be reflected in a total nitrogen analysis of the culture, especially if the result be compared with that from another culture grown in the same medium under identical conditions of incubation but without the addition of the compound in question.

It was in pursuance of this principle that the studies herein reported were made. In the choice of organic compounds, the writers were directed chiefly to those which have already been studied with reference to their effect on the development of higher plants, many of which have been isolated from the soil, and are known to be likewise constituents of various plants.[3] The compounds used were the pure chemical reagents. An effort was made also, that they represent the various groups of organic substances likely to be present in the soil or plant.[4]

[1]Hoffmann and Hammer. Some Factors concerned in the Fixation of Nitrogen by Azotobacter. Centralbl. f. Bakt., Abt. II. Bd. 28, 1910, pp. 127-139.
[2]Ashby, Jour. Agr. Sci., Vol. 2, 1907, pp. 35-48; Gerlach u. Stensen, H. R. Eine biologische Methode fur die Bestimmung von Alkalikarbonaten im Erboden. Centralbl. f. Bakt. Abt. II, Bd. 19, 1907, pp. 735-736.
[3]Shorey, E. C. The Presence of Some Benzene Derivatives in Soils. Jour. Agr. Research. Vol. I, 1914, p. 357.
[4]The sample of dihydroxystearic acid was kindly furnished by Dr. Oswald Schreiner of Bur. of Soils, Washington, D. C.

Plan of the Experiment.

One-litre Erlenmeyer flasks, to which were added 15 grams of pure sea sand, previously washed and burned, afforded an excellent surface upon which Azotobacter developed. To each of these flasks were added 100 c. c. of Ashby's medium of the following composition:

Mannite	12	grams
Mono-potassium phosphate	.2	"
Magnesium sulfate	.2	"
Sodium chlorid	.2	"
Calcium sulfate	.1	"
Calcium carbonate	5.0	"
Distilled Water	1,000.0	c. c.

The flasks were sterilized under 15 pounds of steam pressure for 15 minutes. The organic compounds to be tested were liable to suffer decomposition at the temperature employed in sterilization, hence were not added until after the flasks had been sterilized and cooled. After this sterilization, the compounds were introduced into the flasks in desired concentrations and all flasks received equal inoculation of pure cultures of Azotobacter previously grown on Ashby's Agar and suspended in sterile water. Two flasks were set up for each compound in every concentration, that duplication might be afforded; and in many cases four and six flasks were finally run. Two control flasks receiving only inoculation were used to test the fixation power of the culture used. The experiment was run usually in sets of twenty flasks, and all, including the control, were incubated for 21 days at the end of which time nitrogen determinations of the content of each flask were made by the Kjeldahl method.

TABLE I—*The Effect of Certain Organic Compounds in Various Concentrations on the Growth and Fixation of Nitrogen by Azotobacter.*

Compound	Concentration p. p. M.	Milligrams N. per 100 c. c. Medium		
		With organic compounds	Control	Relative fixation in presence of organic compounds
Esculin	500	10.3	10.2	100
Esculin	1,000	11.3	8.4	135
Esculin	2,000	15.1	9.3	162
Esculin	2,000	10.2	5.4	188
Vanillin	500	7.4	10.2	72
Vanillin	1,000	3.6	8.4	43
Daphnetin	500	13.44	15.	89
Daphnetin	1,000	9.2	10.1	92
Cumarin	250	5.6	8.4	68
Cumarin	500	9.2	10.2	90
Pyrocatechin	250	4.5	8.4	53
Pyrocatechin	500	6.1	10.2	59
Heliotropin	500	10.6	10.2	100
Heliotropin	1,000	4.7	8.4	57
Arbutin	500	6.8	5.4	126
Arbutin	1,000	8.9	9.3	95
Resorcin	500	8.12	8.7	93
Pyrogallol	500	8.4	9.3	90
Phloroglucin	250	5.5	8.4	65
Phloroglucin	500	7.8	10.2	77
Hydroquinone	500	0.0	5.4	00
Salicylic Aldehyde	250	0.0	15.	00
Oxalic Acid	500	11.2	15.	75
Oxalic Acid	1,000	11.1	15.	74
Oxalic Acid	1,000	8.8	10.1	87
Oxalic Acid	2,000	7.1	5.4	131
Quinic Acid	500	10.	15.	66
Quinic Acid	1,000	13.4	9.3	144
Quinic Acid	1,000	10.7	5.4	198
Quinic Acid	2,000	10.4	10.2	119
Dihydroxystearic Acid	250	7.7	8.7	87
Dihydroxystearic Acid	500	7.8	9.3	84
Rhamnose	500	8.2	10.2	84
Rhamnose	1,000	7.8	8.4	93
Borneol	500	9.8	15.	65
Borneol	1,000	11.3	9.3	121
Borneol	1,000	7.3	5.4	135
Borneol	1,000	10.9	10.2	107

The objection will be raised that contamination might occur, since the compounds were added to the flasks after the latter had been sterilized. While this was true in some cases, the contamination was not of such nature as to vitiate the results in this particular work. It is extremely unlikely that any organisms introduced in this manner would affect nitrogen fixation. To test this point a series of flasks were set up with the compounds added after sterilization but receiving no inoculation. There were, indeed, some which exhibited evidence of contamination, yet none showed any perceptible gain or loss in nitrogen. The same strain of Azotobacter was not used in every set of experiments since it is probable that this organism loses some of its virulence when kept for some time under laboratory conditions. But all comparisons were made with the same culture, that is, the control represents the growth of the culture without the compound as compared to the corresponding strain with it.

Table I gives the effect of adding certain non-nitrogenous compounds in various concentrations to the culture nutrient. The results are the averages from analyses of two or more flasks, all of which narrowly approached each other.

TABLE II.—*The Effect of Certain Nitrogenous Organic Compounds in Various Concentrations on the Growth and Fixation of Nitrogen by Azotobacter.*

Compound	Concentration p. p. M.	Milligrams N. fixed per 100 c. c. Medium — With organic compounds	Control	Relative fixation in presence of organic compounds
Caffeine	500	11.8	10.2	115
Caffeine	1,000	9.1	8.4	108
Caffeine	2,000	6.3	5.4	116
Betaine Hydrochloride	500	6.8	15.	45
Trimethylamine	500	4.2	8.7	48
Legumin	500	8.9	9.3	95
Alloxan	500	13.6	10.2	133
Alloxan	1,000	6.4	8.2	78
Alloxan	2,000	5.02	10.1	49
Cinnamic Acid	500	4.5	10.2	44
Cinnamic Acid	1,000	7.2	8.4	85
Cinnamic Acid	2,000	4.5	5.4	83
Asparaginic Acid	500	7.2	15.	48
Asparagine	500	5.4	8.4	65
Asparagine	1,000	5.3	8.4	63
Asparagine	2,000	0.0	15.	00
Hippuric Acid	500	8.	8.4	95
Hippuric Acid	1,000	8.3	8.4	98
Hippuric Acid	2,000	4.02	5.4	74
Creatine	500	8.	8.7	88
Creatine	1,000	5.3	15.1	35
Creatinine	500	8.8	8.7	111
Creatinine	1,000	7.	15.1	46
Xanthine	500	5.6	8.7	64
Xanthine	1,000	5.2	15.1	34
Hypoxanthine	500	4.1	8.7	47
Hypoxanthine	1,000	2.1	15.1	132

In studying compounds which contain nitrogen it was obviously necessary to take into account the amount of nitrogen added before the fixation could be measured. Accordingly, four flasks instead of two were set up with each compound in these experiments, two of the flasks receiving inoculation with Azotobacter and the remaining two receiving only the organic

nitrogen compound but were not inoculated. These latter flasks were kept in the incubator room during the period of incubation that they might be subjected to the same conditions as those growing the culture. It was thought that the temperature of the incubator room might have some effect on the more unstable compounds used, causing a possible loss of nitrogen, but such loss was not found to occur. Table II summarizes the effect of some of these compounds on Azotobacter growth. The figures represent the gain in nitrogen above that added in the compound.

So strikingly did some of the nitrogenous bodies depress fixation, either through toxic properties or by affording a form of nitrogen readily utilized by Azotobacter, that it appears convenient to list them in a separate table. They are arranged in Table III, which follows.

TABLE III—*Nitrogenous Compounds Which Strikingly Depress Fixation by Azotobacter*

Compound	Concentration p. p. M.	Milligrams N. per 100 c. c. of Medium		
		With organic compounds	Control	Relative fixation in presence of organic compounds
Urea	250	6.2	8.4	73
Urea	500	0.0	8.4	00
Urea	500	0.0	15.1	00
Urea	500	0.0	10.1	00
Formamide	500	1.1	15.1	7
Formamide	500	2.2	8.7	25
Formamide	500	0.0	10.1	00
Glycocoll	500	3.1	10.2	30
Glycocoll	500	3.7	10.1	36
Glycocoll	1,000	0.0	10.2	00
Allantoin	500	0.0	8.7	00
Allantoin	500	2.9	15.1	12
Allantoin	500	2.4	10.1	23
Guanidine Carbonate	500	0.0	15.	00
Nicotine	250	2.7	15.	18
Nicotine	500	0.0	15.	00
Picoline	500	3.8	8.7	43
Skatol	500	3.5	8.7	40
Piperidine Hydrochloride	500	4.5	8.7	51

Parts per million, it will be noted, are milligrams per liter and concentrations of 250, 500, 1000, and 2000 p. p. M. represent quantities of .025, .05, .1, and .2 grams per 100 c. c. respectively. In 100 c. c. they may be regarded also as percent. The concentration of 500 parts per million was the first used with most of the compounds as it was assumed that many of them would be decidedly toxic or fatal in this strength, and a gradation would be made downward.

A consideration of Table I, however, shows the indifference with which most of the compounds affect fixation. There is, to be sure, almost a uniform depression, with the notable exception of Esculin, Quinic Acid and Borneol, but it is not to the extent which might be expected from the nature of the compounds. With the exception of Pyrogallol, Hydroquinone, Salicylic Aldehyde, and Oxalic Acid, all[1] of the compounds in Table I have been studied with reference to their effect on the growth of wheat plants,[2] and all reported fatal in concentration as high as 500 p. p. M., and many at strengths decidedly below that figure. They are apparently not as toxic for Azotobacter. The stimulation which Esculin and Quinic Acid afford is significant. Both compounds are reported fatal to wheat seedlings at 500 parts per million, yet above this figure they offer a striking stimulation to Azotobacter's growth. Hydroquinone and Salicylic Aldehyde present the most marked toxic effects. Yet aside from these compounds it does not appear that any of those reported in Table I are especially active in influencing fixation. It is entirely possible that toxic bodies have been changed to non-toxic through oxidations wrought by the bacteria.

Somewhat similar to the effect noted in Table I is that evidenced by the nitrogenous bodies as tabulated in Table II—there are few instances of decided toxicity. Trimethylamine and Alloxan are most noticeable in this respect. Caffeine consistently affords stimulation. There are few of the compounds, however, from which an inhibiting effect might be expected. Indeed, previous studies[3] of Asparagine, Creatine, Creatinine, Xanthine, and Hypoxanthine report them beneficial to higher plants. It is suggested that the compounds are absorbed by the plants with a beneficial effect comparable even to that afforded by nitrates. The compounds in question appear too complex to be utilized by Azotobacter as a source of nitrogen—which fact would be evidenced by no gain in nitrogen over that originally added—and neither do they exhibit any marked deleterious effect save in the higher concentrations.

---

[1]The properties and reports on the toxicity of all of the compounds studied in this paper are tabulated at the end of the article.

[2]Schreiner, Reed and Skinner. Certain organic constitutents of soils in their relation to soil fertility. U. S. Dept. Agr. Bureau of Soils. Bulletin No. 47. Dihydroxystearic Acid reported in Bureau of Soils, Bulletin No. 53.

[3]Schreiner and Skinner. Nitrogenous Soil Constituents and their bearing on Soil Fertility. U. S. Dept. Agr. Bureau of Soils. Bull. 87.

In contrast to the results reported in the preceding tables are those shown in Table III. The action of the compounds here is decisive—there is little fixation in the presence of any of them and with some the process is inhibited altogether. It is clearly a condition of toxicity with the compounds Nicotine, Picoline, Skatol, Guanidine, and Piperidine. These substances are notorious for their inimical effect on plant growth and their action in this case could scarcely be ascribed to any cause other than their natural toxic properties. But with such compounds as Urea, Glycocoll, Formamide, and Allantoin, a possibility presents itself which may be considered as an influencing factor with many of the nitrogenous compounds—the utilization by Azotobacter of the nitrogen supplied by the compounds in preference to that of the atmosphere.

A number of the compounds in question have been shown to be readily assimilated by the higher plants. Urea, Glycocoll, Formamide, can be utilized by peas[1] as a source of nitrogen. It is significant that these compounds so strikingly depress fixation. They present, perhaps, the simplest forms of nitrogen of any of the organic compounds and are therefore most readily utilized. As a result, Azotobacter does not exercise its ability to fix atmosphere nitrogen and there is no gain noted in the final analysis. A similar explanation may be offered to account for the apparent toxicity of such compounds as Creatine, Creatinine, Xanthine, Hypoxanthine, Asparagine and Allantoin. A previous reference has noted the beneficial effect exerted by these compounds on the growth of higher plants, ascribing it to the ability of the plants to ultilize the compounds as a source of nitrogen. Most of these compounds are, however, somewhat complex and it is doubtful if they are assimilated to an appreciable degree by Azotobacter. The interesting point of the whole condition is that the simplest nitrogenous compounds studied, which are readily assimilated by higher plants and which have no general toxic properties, most uniformly depress fixation. It is suggestive of the fact that they may afford a convenient form of nitrogen for Azotobacter and other forms of bacteria.

There was also another condition of the experiment which must not be overlooked in the interpretation of results noted herein. Calcium carbonate was consistently used in Ashby's solution throughout the work in the proportion of 5 grams per litre. It is not unlikely that this substance exerted a decisive effect on some of the organic compounds used in the experiment. It has been shown to have the property of ameliorating the toxic condition of the extract of infertile soils and likewise of overcoming the inimical effect of adding certain substances to nutrient solu-

[1]Hutchinson and Miller. The Direct Assimilation of Inorganic and Organic Forms of Nitrogen by Higher Plants. Centralbl. f. Bakt, Abt. II, Bd. 30, 1911, p. 513.

tions for higher plants.[1] In many cases, especially where acids were added, the $CaCO_3$ doubtless interacted with the compound, forming a calcium salt, and the salts of the compounds are seemingly less toxic than the compounds themselves.[2] Just how qualifying the presence of the $CaCO_3$ was is difficult to say, yet its consistent use with all the compounds insured uniformity and the relative toxicity of each was not materially disturbed.

SUMMARY.

The foregoing paper reports a study on the effect of various organic compounds on the growth of Azotobacter. The study was induced by the theory that the soil contains organic substances which are deleterious to plant growth and which are important factors in influencing soil fertility. It is, therefore, interesting to determine if this toxicity extends to the lower plants. Azotobacter was chosen as a representative of the soil flora since it is of recognized importance in the maintenance of soil fertility and its growth may be accurately measured by analytical means. The compounds used were those likely to be constituents of the soil.

The results of the study indicate that fixation of nitrogen by Azotobacter is only slightly influenced by most of the compounds investigated. A depression is noted in many cases but it is usually the result of a relatively high concentration of the compound used.

Hydroquinone and Salicylic Aldehyde revealed the most toxic properties of any compounds studied.

Esculin, Quinic Acid and Borneol afforded marked stimulation to the growth of the organism.

The effects of the compounds on Azotobacter are not, as a rule, in accord with what has been reported of their action on the higher plants. In concentrations which are fatal to certain higher plants, many of the compounds only slightly depressed fixation.

A number of nitrogenous bodies were investigated. Such compounds as Nicotine, Picoline, Guanidine, and Skatol exhibited toxic properties commensurate to those usually ascribed to these substances. Caffeine appeared to stimulate the growth of the organism.

Many of the nitrogenous compounds used which have been reported as beneficial to higher plants exercised a marked depression on fixation. It appears that the simpler compounds were more pronounced in this respect than were the more complex ones. It is suggested that this condition is not one of toxicity, but that the nitrogen of the compounds was utilized by Azotobacter in preference to that of the atmosphere. Urea, Glycocoll, Formamide, and Allantoin were especially active in depressing fixation.

[1]Livingston, Britton, Reid. U. S. Dept. Agr. Bureau of Soils. Bulletin No. 28; Schreiner, Reed and Skinner—U. S. Dept. Agr. Bureau of Soils. Bulletin No. 47, pp. 44-52.
[2]Schreiner and Shorey. U. S. Dept. Agr. Bureau of Soils. Bulletin No. 53.

LIST OF THE ORGANIC COMPOUNDS STUDIED, SHOWING THEIR OCCURRENCE AND POSSIBLE SOURCE IN THE SOIL, TOGETHER WITH REPORTS ON THEIR ACTION TOWARDS HIGHER PLANTS.

Esculin[1] $C_{15}H_{16}O_9$ has been found in the bark of chestnut and other plants. It has been reported injurious to wheat plants in concentration of 1 p. p. M. and fatal above 500 p. p. M.

Vanillin[1] $C_6H_3\begin{cases}CHO\\ O.CH_3\\ OH\end{cases}$ occurs in the vanilla beans and has been reported in oats, white lupine, raw beet sugar, etc. It is toxic to wheat plants in practically all concentrations and fatal above 500 p. p. M.

Daphnetin[1] $(OH)_2C_6H_4\begin{cases}CH:CH\\ \qquad\;\;|\\ O - CO\end{cases}$ occurs in species of Daphne and is related to Cumarin. It is reported insoluble above 50 p. p. M., but is toxic to wheat in that concentration.

Cumarin[1] $C_6H_4\begin{cases}CH:CH\\ \qquad\;\;|\\ O - CO\end{cases}$ is said to occur in certain grasses, clover, beets, and other plants. It exhibits toxicity to wheat in concentration of 1 p. p. M., and is fatal at 100 p. p. M.

Pyrocatechin[1] $C_6H_4\begin{cases}OH\\ OH\end{cases}$ occurs in the sap of certain trees and in leaves of various plants. Concentrations of 1 p. p. M. offered a slight stimulation to wheat; 25 p. p. M. caused slight injury, and 500 p. p. M. was fatal.

Heliotropin[1] $C_6H_3\begin{cases}CHO\\ O\diagdown\\ \qquad CH_2\\ O\diagup\end{cases}$ is found in certain flowers. It is toxic to wheat in small concentrations but not fatal to growth in quantities as high as 1,000 p. p. M.

Arbutin[1] $C_{12}H_{16}O_7$ is a glucoside of hydroquinone and is widely distributed in plants. It is reported toxic to wheat at 25 p. p. M. and fatal at 500 p. p. M.

Resorcin[1] $C_6H_4\begin{cases}OH\\ OH\end{cases}$ is derived from resin which is found in a number of plants.

Pyrogallol[1] $C_6H_3\begin{cases}OH\\ OH\\ OH\end{cases}$ in solutions above 25 p. p. M. is reported toxic to wheat plants.

Phloroglucine[1] $C_6H_3\begin{cases}OH\\OH\\OH\end{cases}$ is not found in plants, but is derived from several plant constituents. It causes injury to wheat in concentrations of 25 p. p. M. and is fatal at 500 p. p. M.

Hydroquinone $C_6H_4\begin{cases}OH\\OH\end{cases}$ is closely related to Quinone[1] which is sometimes found in the soil. It is toxic to wheat plants in all concentrations.

Salicylic Aldehyde[2] $C_6H_4\begin{matrix}\diagup OH\\ \diagdown CHO\end{matrix}$ occurs in the blossoms of certain plants. It has been isolated from the soil also.

Oxalic Acid $\begin{matrix}COOH\\|\\COOH\end{matrix}$ has been found in soils probably as Calcium Oxalate. It is a common product of decomposing organic plant constituents.

Quinic Acid[1] $C_6H_7(OH)_4COOH$ is found in cinchona bark, always accompanying Quinine. It is reported to stimulate wheat below concentrations of 500 p. p. M., but is extremely toxic above 500 p. p. M.

Dihydroxystearic Acid[3] $\begin{matrix}CH_3, & (CH_2)_7 & CHOH\\ COOH & (CH_2)_7 & CHOH\end{matrix}$ has been isolated from a number of soils. It is reported toxic to wheat plants in very minute concentrations.

Rhamnose[2] $C_6H_{12}O_5$ has been derived from a glucoside isolated from the soil. It may also be obtained from a number of glucosides which occur widespread in plants.

Borneol[1] $C_{10}H_{17}(OH)$ is a representative of the camphor group and occurs in needles of pine and fir trees. It is quite insoluble. It is reported toxic to wheat at 1 p. p. M. and fatal at 100 p. p. M.

Caffeine $C_8H_{10}O_2N_4$ is found in leaves and beans of the coffee tree, in tea, cocoa, etc. It is closely related to Xanthine.

Betaine[1] $(CH_3)_3\,N\begin{matrix}\diagup CH_2CO\\ \diagdown O\end{matrix}$ occurs in the juice of sugar beets and in many seeds and plants. It is reported beneficial to wheat in concentrations of from 5 to 1,000 p. p. M.

Trimethylamine[2] $\begin{matrix}CH_3\diagdown\\ CH_3\quad\\ CH_3\diagup\end{matrix}N$ has been isolated from soils. It occurs in plant and animal tissues.

Legumin occurs in the seeds of a number of plants, especially the lupines.

Alloxan[1] $CO\begin{matrix}\diagup NHCO\diagdown\\ \diagdown NHCO\diagup\end{matrix}CO$ is closely related to compounds which occur

in plants. It is readily assimilated by peas.[1] It is reported toxic to wheat above 100 p. p. M.

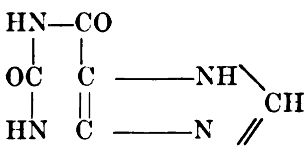
Cinnamic Acid[1] $C_6H_5CH{:}CH.COOH$ is found in resin balsam, storax, and arises in the decomposition of certain alkaloids. It is reported toxic to wheat at 25 p. p. M. and fatal above 100 p. p. M.

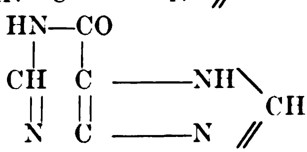
Aspartic Acid[1] $COOH.CH_2CH(NH)_2COOH$ is found in young sugar cane and beets and in the seed of various plants. It is fatal to wheat plants in concentrations of 500 p. p. M.

Asparagine[1] $\begin{array}{l}CH_2.CONH_2\\ |\\ CH(NH_2).COOH\end{array}$ occurs in young shoots of asparagus plants and in many other plants. It is reported favorable to wheat grown in solutions without nitrate. Its beneficial action decreases with increased nitrates.

Hippuric Acid[1] $CH_2\begin{array}{l}\diagup NH.CO.C_6H_5\\ \diagdown CO_2H\end{array}$ occurs in the urine of herbivorous animals. It is reported only slightly assimilated by peas.

Creatine $NH{:}C\begin{array}{l}\diagup NH_2 \quad COOH\\ \qquad\qquad\quad |\\ \diagdown N(CH_3)CH_2\end{array}$ and Creatinine[5] $NH{:}C\begin{array}{l}\diagup NH - CO\\ \diagdown N(CH_3)CH_2\end{array}$ are closely related chemically. The latter occurs in soils, is widely distributed in seeds and is a constitutent of manures and animal flesh. Both are oxidation products of Guanidine. They have been shown to exert a beneficial effect on wheat plants.[6] The stimulation is not so marked in the presence of nitrates.

Xanthine  and

Hypoxanthine[6]  are closely related chemically and occur widely in soils. They are related to Uric Acid. They have been reported favorable to the growth of wheat.

Urea[4] $CO\begin{array}{l}\diagup NH_2\\ \diagdown NH_2\end{array}$ occurs in the excreta of animals and therefore in manures. It is reported as readily assimilated by peas.

Formamide[1] $CO\begin{array}{l}\diagup N\\ \diagdown NH_2\end{array}$ is reported assimilated by peas.

Glycocoll[1] $CH_2\begin{matrix}/NH_2\\ \backslash COOH\end{matrix}$ is a product of the decomposition of proteins. It is directly assimilated by peas.[4] It is reported beneficial to wheat in concentrations of 1,000 p. p. M.

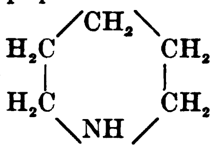
Allantoin[6] $CO\begin{matrix}/NHCO\\ \backslash NHCHNH.CONH_2\end{matrix}$ is an oxidation product of Uric Acid which is reported as assimilated by oats. It is reported as without any perceptible effect on wheat.

Guanidine[1] $NH\begin{matrix}/NH_2\\ \backslash NH_2\end{matrix}$ is found in many plants and is derived by oxidation from Arginine, which is found in plants and in soils. It is reported fatal to wheat plants in concentrations of 100 p. p. M.

Nicotine $C_{10}H_{14}N_2$ occurs extensively in the tobacco plant.

Picoline[1] $C_5H_4NCH_3$ is a decomposition product of several of the alkaloids. It is toxic to wheat above 500 p. p. M. and fatal at 1,000 p. p. M.

Skatol[1] $C_6H_4\begin{matrix}/C.CH_3\backslash\\ \backslash NH=/\!/\end{matrix}CH$ is a common product of protein decomposition and is formed through the action of bacteria. It is reported injurious to wheat at 50 p. p. M. and fatal at 200 p. p. M.

Piperidine[1]  is a constituent of pepper and present in many alkaloids. It is fatal to wheat seedlings at 250 p. p. M.

References From the Foregoing List.

1. Schreiner, Reed and Skinner. Certain Organic Constituents of Soils in Relation to Soil Fertility. U. S. Dept. Agr. Bur. of Soils. Bulletin 47.
2. Shorey, Edmund C. Some Organic Soil Constituents. U. S. Dept. Agr. Bur. of Soils. Bulletin No. 88.
3. Schreiner and Lathrop. Examination of Soils for Organic Constituents. especially Dihydroxystearic Acid. U. S. Dept. Agr. Bur. of Soils. Bulletin No. 80.
4. Hutchinson and Miller. The Direct Assimilation of Inorganic and Organic Forms of Nitrogen by Higher Plants. Centralbl. f. Bakt. Abt II. Bd. 30., Schreiner, Shorey, Sulivan, Skinner, p. 513.
5. A Beneficial Organic Constituent of Soils: Creatinine. U. S. Dept. Agr. Bur. of Soils. Bulletin No. 83.
6. Schreiner and Skinner. Nitrogenous Soil Constituents and their Bearing on Soil Fertility. U. S. Dept. Agr. Bur. of Soils. Bulletin No. 87.

SOME EFFECTS OF PRUNING, ROOT PRUNING, RINGING AND STRIPPING ON THE FORMATION OF FRUIT BUDS ON DWARF APPLE TREES.

By A. W. Drinkard, Jr.

The experiments reported in this paper were begun for the purpose of determining the effects of pruning, root pruning, ringing and stripping at different seasons on the formation of fruit buds on apple trees. These experiments were begun in the spring of 1913, and at the present time a report of progress on the work seems desirable. The work has been extended to include half dwarf and standard apple trees, and it is planned to observe the behavior of the trees when so treated under a variety of conditions in order that generalizations of value to the fruit grower may be made.

The trees used in the experiments herein reported were full dwarf apple trees, an English variety known as King of Pippins. These dwarf trees were planted on the grounds of the Experiment Station in April, 1908. At the time of setting the trees were one year old, straight whips, budded on Paradise stocks, well grown and very uniform. The trees were set in squares 6.6 feet apart, and when planted were cut back to stubs 15 to 21 inches in height. In the spring of 1909, the trees were pruned to the central shaft system, retaining three to five lateral branches subordinate to the leader. From this time to the spring of 1913, these trees received very light pruning, consisting mainly of thinning where the branches had become too thick, and some light heading-in. When the experiments began, the condition of the trees was as follows: The trees had made fair growth; their branches were too close together and the main trunks as well as the branches were rather spindling. The fact that the trees were planted close together caused them to grow tall with narrow spread of branches. As regards management of this orchard, it received tillage every year followed by a cover crop of crimson clover the 1st or 15th of July, the cover crop being turned under the following year. This practice was continued until August, 1913, at which time grass seed, consisting of a mixture of orchard grass, red top, timothy and red clover was sown, giving a good set and later forming a good sod. This orchard contained 948 trees, of several varieties.

Up to the time these experiments were started the trees of this variety had fruited very sparsely. They had made good growth, were very uniform and were considered well suited for the purpose of these experiments because of the habit of sparse fruiting.

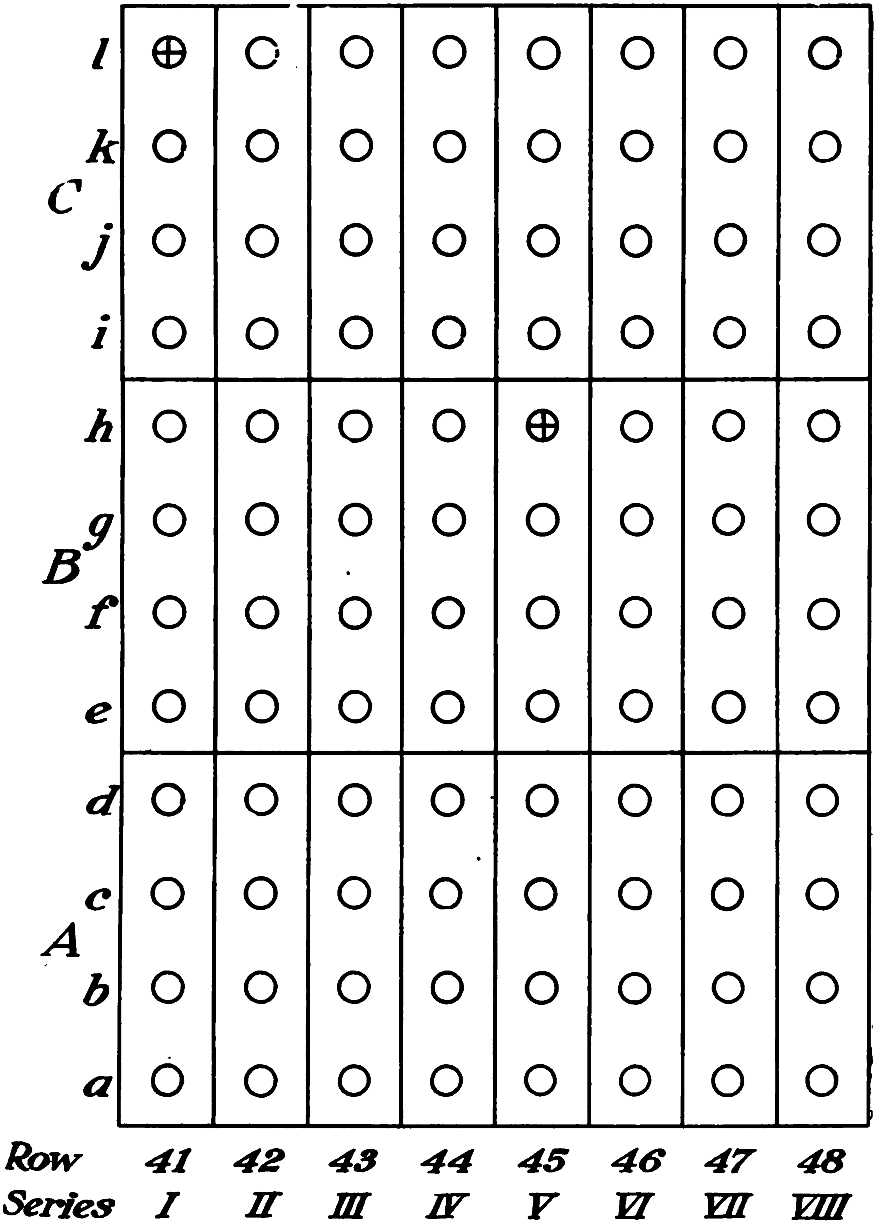


Fig. 1.—Map showing location of the King of Pippins trees in the full dwarf apple orchard, and the division of the block of trees into plats for the pruning experiments. The two trees marked with a circle containing a cross were missing when the experiments were started in the spring of 1913.

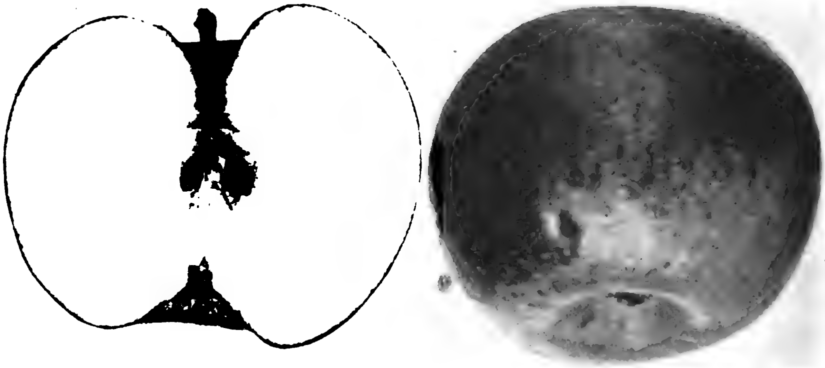


Fig. 2.—Fruit of King of Pippins. This apple is oblate in form, and slightly above medium in size. Its skin has a yellow ground color, washed and striped with bright red with numerous russet dots. The flesh is firm, juicy and light cream color. The flavor is pleasant sub-acid. Its quality is good, and it is ripe in October. This apple is attractive in appearance, and it has dessert quality, but so far it has proved a poor bearer here.

Outline of Pruning Experiments Carried Out in 1913.

I—Pruning at different seasons.
- A. Spring pruning, April 23d, 4 trees.
- B. Summer pruning, June 23d, 4 trees.
- C. Fall pruning, November 21st, 3 trees.

II—Spring pruning on April 23d, accompanied by root pruning.
- A. In spring when the sap began to flow, April 23d, 4 trees.
- B. After the foliage was well developed, May 31st, 4 trees.
- C. When fruit buds began to form, June 23d, 4 trees.

III—No spring pruning; root pruning at following dates:
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

IV—Check Series. No pruning of any kind.
- A. Including 4 trees.
- B. Including 4 trees.
- C. Including 4 trees.

V—Spring pruning on April 23d, accompanied by ringing.
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 3 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

VI—No spring pruning; ringing at following dates:
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

VII—Spring pruning on April 23d, accompanied by stripping.
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

VIII—No spring pruning; stripping on the following dates:
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

A record was made of the number of fruit buds which developed on the trees in this block in the spring of 1913. These data are given in Table 1, and they show that the trees were fairly uniform. These trees produced no fruit this year; killing frosts on April 21st and 22d destroyed the essential flower parts before the bloom opened.

TABLE 1.—*The number of fruit buds which developed on each tree in the block. May 14, 1913.*

C	l	missing	305	535	180	175	15	50	380
	k	80	140	195	50	35	25	0	30
	j	30	95	75	510	10	115	0	35
	i	55	15	230	155	45	80	5	15
B	h	40	5	150	40	missing	20	20	40
	g	60	350	240	65	150	105	0	40
	f	825	0	35	395	85	110	85	30
	e	150	110	135	120	75	370	140	260
A	d	65	360	180	110	55	480	5	65
	c	100	100	375	125	195	155	25	135
	b	20	160	665	110	25	60	25	205
	a	150	95	400	65	90	545	5	50
Series		I	II	III	IV	V	VI	VII	VIII

RECORD OF THE WORK DURING 1913.

It was rather late when the growing season arrived this year. The pruning experiments were started on April 23d. On this date the terminal bud clusters of the King of Pippins were beginning to burst and in a few cases the fruit buds had swelled sufficiently to show the pink color of the petals within. At this date, sap was moving freely in the trees.

SERIES I. PRUNING AT DIFFERENT SEASONS.

Spring pruning.—Plat A. These trees were pruned heavily on April 23d. The branches had become too thick and were running up too high.

Pruning here consisted largely of thinning the branches and heading-in those that remained. Practically the whole of last season's shoot-growth was removed and often it was necessary to cut back two-year wood. Small branches inside the tree, which gave promise of developing into fruiting wood, were not removed and care was taken to protect fruit spurs on the trees. Pruning at this season corresponds in a general way with the practice in most of the commercial orchards of this State, except perhaps this plat was pruned somewhat later than the orchardists prune in commercial work. The apple orchards in this State are generally pruned during the winter and spring.

Summer pruning.—Plat B. These trees were summer pruned on June 23d, which was about the time fruit buds were beginning to form. The pruning here was done in the same way as in plat A of this series. The heading-in of the branches removed many shoots of the current season and reduced the present foliage about 50 percent. It was noted at the end of this season that these trees made very short growth in annual shoots. But these trees held their leaves in a green, active condition until late in the fall.

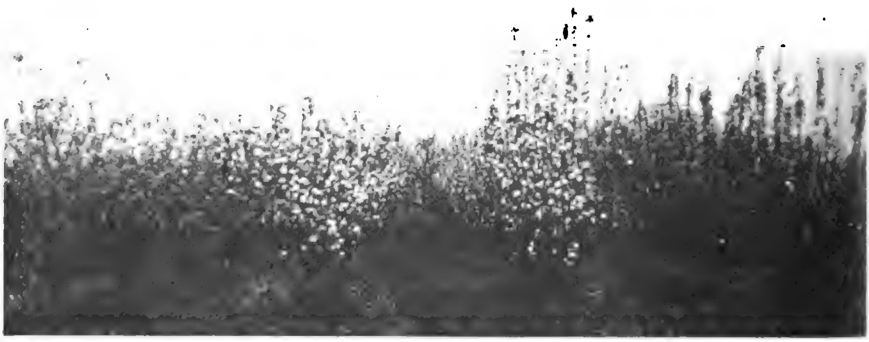


Fig. 3.—A general view of series I (left), II, III and IV (right). The trees in Series II and III, which were root pruned, carry a heavy crop of bloom; while the spring pruned trees (Series I) and the check trees (Series IV) carry very little bloom. Photo May 6, 1914.

Fall pruning.—Plat C. On November 23d, these trees were pruned heavily, following the same method as in plat A. Many of the shoots of the current season were removed; the shoots inside the tree and the fruit spurs were not interfered with.

SERIES II. SPRING PRUNING ACCOMPANIED BY ROOT PRUNING AT DIFFERENT SEASONS.

All of the trees in this series were pruned in the manner described in I A on April 23d. This uniform treatment of the trees was followed by differentiation of time at which the roots were pruned.

Spring pruning accompanied by root pruning at the beginning of sap flow.—Plat A. The trees in this plat were root pruned on April 23d. A spade was used to remove the soil sufficiently to expose the roots of the trees. The roots were then cut off with a hatchet or a pruning knife, care being taken to make a smooth wound. The roots were severed at varying distances from the crown of the tree; sometimes twelve inches, sometimes eight inches and sometimes less than six inches from the crown. Many of the fibrous feeding roots were thus destroyed. The tree was root pruned all around, and below as well. When the process was complete one could lift the tree very readily. This was very severe root pruning. After the root pruning was accomplished, the soil was replaced around the tree and tamped firmly to hold the tree in position. Later, in the summer of this year at a time when the soil was very wet and soft, several of the root pruned trees were blown over by strong wind. These were replaced again and held in position firmly by binding them to stakes which were driven into the ground. In practice, the orchardist would not prune the roots of fruit trees so heavily as was done in this experiment. But the object here was to make the conditions such that positive results would be secured. It is likely that more moderate root pruning would give similar results in degree proportional to the severity of the treatment. The trees in this plat made very poor growth during the summer, and the new leaves which developed later in the season were very small.

Spring pruning accompanied by root pruning at the time the foliage attained full development.—Plat B. These trees were root pruned on May 31st. The leaves on these dwarf apple trees had come to full size and the foliage was fully developed on this date. The process of root pruning was carried out in a manner similar to that described in II A. It was noticeable through the remainder of the season that further development of leaves and the growth of woody shoots was greatly retarded by the treatment.

Spring pruning accompanied by root pruning at the time fruit buds began to form.—Plat C. The trees in this plat were root pruned on June 23d, as described for II A. Evidence has been secured at this Station showing that the differentiation of fruit buds begins the latter part of June.* The trees in this plat had better opportunity for growth of their leaves and shoots before the root pruning was performed. Hence, it appeared in the fall of this year that the trees in this plat were in better condition than the trees of plats A and B of this series.

SERIES III. ROOT PRUNING WITHOUT ANY PRUNING OF THE TREE TOPS.

The trees in this series offer an opportunity for studying the effects of root pruning without any of the complications which might arise from the

*Drinkard. A. W., Jr., Fruit Bud Formation and Development. Annual Rpt. Virginia Agr. Exp. Sta. for 1909 and 1910, pp. 159-205.

usual pruning of the trees in the spring. The tops of the trees were left just as they happened to be at the beginning of the experiments; in many cases the branches were too thick and were in need of thinning and heading-in.

Root pruning at the beginning of sap flow.—Plat A. The trees in this plat were root pruned on April 23d. The root pruning was done as in the case of II A. These trees made poor growth during the summer.

Root pruning when the foliage was well developed.—Plat B. These trees were root pruned on May 31st. During the summer these trees made better growth than those of Plat A, because the former had no time to develop shoots and foliage before the roots were pruned. The trees in this plat were root pruned as in the case of II A.

Root pruning at the time the fruit buds began to form.—Plat C. These trees were root pruned on June 23d. The trees in this plat made better growth during the summer than the trees in plats A and B of this series.

SERIES IV. CHECK TREES. NO PRUNING.

The twelve trees in this series were not pruned, but were left as controls so that trees in the treated series might be compared with these controls. These check trees made a uniform growth during the summer.

SERIES V. SPRING PRUNING ACCOMPANIED BY RINGING.

All of the trees in this series were top pruned on April 23d as in the case of I A. After this common treatment the trees were ringed at different seasons as indicated in the paragraphs which follow.

Spring pruning accompanied by ringing at the beginning of sap flow.—Plat A. The trees in this plat were ringed on April 23d. Ringing consisted of the removal of a band of bark, one-fourth to one-half inch in width, from the trunk of the tree, eight to twelve inches above the ground. A knife was used for the operation. The bark, including the bast and cortex, was cut through, after which it peeled readily. No difficulties appeared in the healing of these wounds. The wood cambium regenerated the bark in the course of the season. The following year in similar experiments it was found that the wounds made at the resumption of growth in the spring did not heal well because there was considerable opportunity for drying out before the healing process began. This indicates that as a general practice ringing should not be done until growth is well under way and the wound should be relatively small. This break produced in the continuity of the cortex by the ring, permits the upward movement of water from the roots carrying plant food in solution, but does not permit the return to the roots of organic nutrient materials which have been elabo-

rated in the leaves. The shoot growth on the trees in this plat was rather short.

Spring pruning accompanied by ringing at the time the foliage was well developed.—Plat B. These trees were ringed on May 31st. The process was the same as in V A. The growth of these trees seemed to be slightly better than the growth of the trees in plat A of this series. The wounds healed well.

Spring pruning accompanied by ringing at the time the fruit buds began to form.—Plat C. The trees in this plat were ringed on June 23d, in the same manner as the trees of V A. These trees made a better growth than those on plats A and B of this series. The wounds did not heal perfectly in plat C. New bark was regenerated over the greater part of the wound area; but spots remained here and there which became dry, leaving a permanent wound.

SERIES VI. RINGING WITHOUT SPRING PRUNING.

The trees in this series gave an opportunity to study the effects of ringing when the factor of spring pruning was eliminated. The twelve trees in this series were not top pruned this year. They were left just as they happened to be at the time the experiments were started. Aside from the fact that the tops were not pruned, the three plats A, B and C were ringed in exactly the same way and at the same time as the trees in plats A, B and C of series V, respectively. Therefore no further description of the treatment of the plats in series VI is required at this time.

SERIES VII. PRUNING ACCOMPANIED BY STRIPPING.

The twelve trees in this series were top pruned on April 23d as described in series I A. The trees in the three plats were later stripped at different periods as noted below. The process of stripping consisted in the removal of strips of bark one-fourth to one-half inch in width from the trunk of the tree beginning near the surface of the ground and extending up to and frequently above the main branches of the tree. Several of the main branches were stripped for a distance of twelve or eighteen inches. Three to five such strips were taken from each tree. The strip was first marked by the use of a knife point, and then the strip of bark could be peeled from the tree readily.

Spring pruning accompanied by stripping at the time the sap began to flow.—Plat A. These trees were stripped in the manner described above on April 23d. It was noticeable through the season that the trees in this plat made good growth and held their leaves until late in the fall. The stripping wounds healed over very well during the growing season. The stripping operation does not completely cut off the movement of water in

Fig. 4.—Ringing without spring pruning. In the foregound stands tree VI B f, ringed May 31, 1913, and now carries a heavy crop of bloom. The succeeding five trees are VI B e and VI A d, c, b and a respectively; the trees in Plat A were ringed April 23, 1913, and now carry very little bloom, showing that the operation was too early to stimulate fruit bud formation. Photo May 1, 1914.

either direction, but must interfere with the same in some measure, and the stripping operation must administer a shock more or less severe to the growth processes of the tree.

Spring pruning accompanied by stripping at the time the foliage is well developed.—Plat B. The trees in this plat were stripped on May 31st, as described in VII A. During the growing season the wounds healed well, and the trees made excellent growth—equally as good as in the case of VII A.

Spring pruning accompanied by stripping at the time the fruit buds began to form.—Plat C. These trees were stripped on June 23d, as described in VII A. It appeared that stripping at this time interfered with the growth of the trees noticeably, and the stripping wounds did not heal over rapidly. This appeared to be too late to secure the best results from this process.

SERIES VIII. STRIPPING WITHOUT SPRING PRUNING.

Aside from the fact that there was no pruning of the tops, the trees in the three plats of this series were treated in exactly the same way and the operations were performed at the same time as those described in plats A, B and C of series VII, respectively, and the growth of the trees during the season was very similar to that of the trees in series VII.

Fig. 5.—This tree (VI A c) was ringed April 23, 1913, without spring pruning, and has very little bloom. The ringing was too early to stimulate fruit bud formation. Photo May 1, 1914.

RECORD OF TREE GROWTH DURING 1913.

It is obvious that operations designed to influence the formation of fruit buds on trees must at the same time be of such a nature that it will not seriously interfere with the proper growth of the tree. Hence it seemed desirable to make a record of the growth of the trees. The circumference

of the tree trunk was measured about eight inches above the ground. All twigs or shoots of the current season's growth were measured on each tree and the lengths were recorded in inches. From these data the total linear growth of the shoots was determined, and the average linear growth of shoots for a given tree was secured by dividing the total linear growth by the number of twigs measured on that tree. Averages for each plat were secured by dividing the sum of the above values by the number of trees in each plat. These averages are given in Table 2, and it is obvious that the average of the mean growth is not the exact quotient resulting from dividing the average of the total shoot growth by the average number of twigs on a tree. These measurements were made on November 5th.

One may observe from Table 2 that pruning of the tops of the trees during spring apparently stimulated wood growth. Certain other operations, as might have been anticipated, retarded wood growth.

TABLE 2.—*Summary of growth of trees in pruning experiments during the season 1913.*

Series, plat and number of trees in plat	Average Circumference in inches	Average number of twigs per tree	Ann. twig growth in inches	
			Avge. of the total growth	Avge. of the mean growth
I. A. 4 trees	6.7	72	635	8.8
I. B. 4 trees	6.4	26	119	4.7
I. C. 3 trees	6.7	59	438	7.2
II. A. 4 trees	6.4	32	64	1.9
II. B. 4 trees	6.6	73	363	4.7
II. C. 4 trees	6.6	75	525	6.8
III. A. 4 trees	6.0	48	119	2.4
III. B. 4 trees	6.7	56	244	4.3
III. C. 4 trees	7.1	50	266	5.3
IV. A. 4 trees	6.9	44	201	4.6
IV. B. 4 trees	6.7	39	190	4.8
IV. C. 4 trees	7.4	41	176	4.4
V. A. 4 trees	5.6	27	176	6.0
V. B. 3 trees	6.0	26	90	3.2
V. C. 4 trees	6.4	29	170	5.7
VI. A. 4 trees	5.6	31	111	3.6
VI. B. 4 trees	6.0	31	163	5.2
VI. C. 4 trees	6.0	29	125	4.2
VII. A. 4 trees	6.5	26	199	7.5
VII. B. 4 trees	6.2	21	271	13.2
VII. C. 4 trees	6.4	22	184	8.4
VIII. A. 4 trees	6.9	25	116	4.8
VIII. B. 4 trees	6.9	28	156	5.4
VIII. C. 4 trees	7.2	28	131	4.6

RECORD OF RESULTS DURING 1914.

When the fruit bud clusters began to expand it was evident that there were differences in the number of fruit buds which had developed on the trees in the different plats. Table 3 shows the number of fruit buds which developed on each tree. These figures were secured by counting the number of fruit bud clusters on the tree and multiplying the same by five. This point was determined by counting the actual number of fruit buds in a large number of fruit bud clusters, the results of which countings showed that there was a range of 3 to 7 with an average of 5.3 fruit buds for each fruit bud cluster. Therefore the use of the factor 5 may give results slightly below the actual numbers, but the difference is immaterial since the results are relative.

TABLE 3.—*The number of fruit buds on the trees in the pruning experiments, May 2, 1914.*

C	l	missing	1,375	1,750	785	375	760	380	920
	k	295	520	1,375	90	130	200	25	705
	j	205	585	1,625	150	160	2,000	55	790
	i	155	425	5,000	105	1,120	1,425	110	1,140
B	h	385	1,100	5,000	187	missing	2,240	0	485
	g	475	1,340	4,235	95	140	2,400	10	600
	f	80	2,095	2,000	600	260	3,135	30	1,300
	e	240	1,210	1,475	20	1,110	2,030	695	1,750
A	d	10	815	380	105	390	5	35	1,475
	c	15	1,865	45	355	160	60	55	1,425
	b	15	895	1,500	205	190	125	20	1,635
	a	45	1,500	1,400	100	30	1,475	50	1,460
Series		1	II	III	IV	V	VI	VII	VIII

It seems clear from a study of Table 3 that the several treatments applied to the trees of the different plats in these experiments were more or less efficacious in stimulating the formation of fruit buds. Allowance must be made for the individual variation of the trees, and for the small number of trees included in each plat; but after these variables are considered there still remain in many cases differences in fruit bud formation that can be attributed only to the treatment which the trees received. For the present a detailed discussion of Table 3 may be deferred in order that record may be given of the subsequent behavior of these trees during the remainder of the growing season.

On June 15th, after the period for the "June drop" had passed, record was made of the number of fruits which had set on each tree. It is well known that relatively few of the fruit buds which normally develop on an apple tree continue to develop into fruit. Table 4 shows that a very large

percent of the fruit buds failed to set. The frequency of death of fruit buds was especially high on the trees which were root pruned.

Table 5 shows the number of fruits which actually came to maturity and were harvested from the different trees on the plats.

TABLE 4.—*The number of apples which set on the trees in the pruning experiments; records made after "June drop," June 15, 1914.*

C	l	missing	42	71	249	51	56	55	90
	k	72	17	75	12	22	20	7	42
	j	66	52	69	27	26	91	13	98
	i	60	60	148	41	112	131	19	58
B	h	155	70	42	4	missing	135	0	46
	g	178	35	23	22	22	145	4	93
	f	26	30	44	60	29	77	7	83
	e	64	0	11	6	87	41	69	91
A	d	0	32	25	24	66	0	12	84
	c	3	35	0	63	38	8	14	86
	b	5	57	14	25	14	4	6	110
	a	10	42	17	29	18	132	10	112
Series		1	II	III	IV	V	VI	VII	VIII

TABLE 5.—*The number of fruits which were harvested from the trees in the pruning experiments, September 19, 1914.*

C	l	missing	37	47	100	51	50	35	44
	k	53	5	67	23	15	14	2	43
	j	33	70	63	29	27	89	12	68
	i	42	60	144	40	110	125	20	49
B	h	114	88	38	35	missing	106	0	48
	g	131	40	19	23	20	100	2	70
	f	13	30	37	63	41	60	12	82
	e	48	1	8	2	73	34	77	88
A	d	0	35	17	23	54	1	12	75
	c	3	35	0	38	32	3	16	78
	b	5	50	14	24	13	7	3	88
	a	6	38	11	21	3	91	8	50
Series		1	II	III	IV	V	VI	VII	VIII

Obviously, it is important to know whether the pruning operation employed interferes with the normal growth of the tree. The growth of the trees was measured in the fall of 1914 just as it was done the preceding year. A summary of these measurements is given in Table 6.

TABLE 6.—*Summary of growth of trees in pruning experiments during the season 1914.*

Series, plat and number of trees in each plat	Average Circumference in inches	Average number of twigs per tree	Ann. twig growth in inches	
			Avge. of the total growth	Avge. of the mean growth
I. A. 4 trees	7.2	79	545	6.9
I. B. 4 trees	6.9	57	397	6.9
I. C. 3 trees	7.6	63	599	9.7
II. A. 4 trees	6.4	54	143	2.7
II. B. 4 trees	6.7	60	227	3.8
II. C. 4 trees	6.5	36	89	2.2
III. A. 4 trees	5.9	36	77	2.1
III. B. 4 trees	6.8	13	22	1.6
III. C. 4 trees	7.2	22	30	1.3
IV. A. 4 trees	7.1	44	207	4.7
IV. B. 4 trees	7.0	37	162	4.2
IV. C. 4 trees	8.3	56	258	4.1
V. A. 4 trees	6.2	43	225	5.0
V. B. 3 trees	6.3	38	145	3.9
V. C. 4 trees	6.7	46	254	5.4
VI. A. 4 trees	6.3	29	103	3.6
VI. B. 4 trees	6.1	29	136	4.7
VI. C. 4 trees	6.4	31	114	3.7
VII. A. 4 trees	7.1	46	299	5.8
VII. B. 4 trees	6.8	41	283	6.7
VII. C. 4 trees	7.0	43	257	5.9
VIII. A. 4 trees	7.0	40	225	5.7
VIII. B. 4 trees	7.1	40	184	4.6
VIII. C. 4 trees	7.9	39	160	4.0

During the year 1914, no pruning of any kind was done on the trees in these experiments, the object being to study the residual effect of the treatments applied the previous year; and the plan is to leave these trees unpruned so long as these treatments yield evidence of continued influence on the formation of fruit buds. There is now a good sod on the land where the trees stand, and from time to time through the summer the grass was cut with a scythe and left to lie on the land as a mulch. In the spring of this year a liberal top dressing of stable manure was applied to the land. The season was unfavorable for the experiment because of prolonged drought. There was very light rainfall during the months of April, May and June. Table 7 shows the relative amount of rainfall during this period. Several times during this dry period water was hauled and applied to the plats which had been root pruned.

TABLE 7.—*Amount of rainfall (expressed in inches) at Blacksburg, Virginia, for the time indicated.*

	April	May	June
1914	2.38	.76	.63
Average for the preceding 10 years	3.40	4.17	5.14

The trees in the pruning experiments received the usual dormant spray and the summer sprays for insects and diseases. General observations on the experiments during the year 1914 and discussion of the results will now be given.

DISCUSSION OF RESULTS FOR 1914.

SERIES I. PRUNING AT DIFFERENT SEASONS.

Spring pruning.—Plat A. The trees in this plat produced fewer buds than the check trees; the set of fruit was very light; the shoot and trunk circumference growth were decidedly better than the checks, and foliage during the growing season was better than that of the check trees. These trees give some evidence on the proposition which several horticulturists have advanced in recent years that heavy winter or spring pruning stimulates wood growth and discourages the development of fruit buds.

The stimulation of wood growth does not mean necessarily an increase in the total mass of the tree, as has been pointed out by the Duke of Bedford and Pickering.[1] From their studies of this question these authors were of the opinion that hard pruning did not ultimately result in a larger tree than light pruning. In later experiments these authors[2] found that the less a tree was pruned the greater was its wood growth, except in case of old trees, on which the amount of wood was increased by hard pruning; that hard pruning was antagonistic to fruiting, this rule applying to both young and old trees.

Standing alone, the experiment on this plat of dwarf trees would furnish very meager evidence on the question; but corroborative evidence comes forth from the experiments in which hard spring pruning was combined with root pruning, ringing and stripping. Hard spring pruning uniformly discouraged the development of fruit buds as compared with check trees and trees receiving the same treatments without the pruning of their tops in spring.

In a recent article on pruning, Lewis[3] emphasizes the fact that pruning is to be determined in some measure by the variety in question. He thinks

[1]2nd Rpt. Woburn Exp. Fruit Farm, pp. 106-159. 1900.
[2]7th Rpt. Woburn Exp. Fruit Farm, p. 56. 1907.
[3]Better Fruit 8: No. 9, pp. 11-12. March, 1914.

that many fruit growers are delaying profitable fruiting of young orchards by hard pruning and he suggests that fruiting may be encouraged by lighter pruning.

Summer pruning.—Plat B. The trees in this plat showed an increase in fruit bud development as compared to the checks; there was a very satisfactory set of fruit, which matured in quantity as large as the trees should bear, and the size and quality of the fruit was normal; the trees

Fig. 6.—View of check trees and trees which were root pruned without spring pruning. The check trees (left, the tree in the foreground is IV C 1) carry a light crop of bloom. The root pruned trees (right, the tree in the foreground is III C 1) carry very heavy crop of bloom. Photo May 1, 1914.

bore good foliage during the growing season, but not as heavy as that on the spring pruned trees, nor was the growth of shoots or the increase in circumference of the tree trunk as good as in the case of spring pruned trees. The balance between tree growth and fruit bud development seemed very good. The wounds made in removing branches healed well. In this case summer pruning, performed at the time the fruit buds began to form, stimulated the development of fruit buds. This experiment gives some evidence on the proposition, which is often expressed by horticulturists and practical fruit growers, that summer pruning increases the fruitfulness of apple trees. No doubt the degree of increase in fruitfulness resulting from summer pruning bears direct relations to the condition of the trees, the

season and the time and severity of the operation. The physiological principle involved is not clear. It is obvious that severe summer pruning reduces the foliage area, interfering with transpiration and photosynthesis. The balance between the root system and the branch system is suddenly disturbed. The nutrition of the different organs of the tree is changed in some degree by summer pruning.

Quinn[1] has described the different methods employed in summer pruning, consisting of dis-budding, pinching, thinning, heading-in and fracturing or twisting of branches; he found that these operations were effective in greater or less degree for conditions in Australia. Dickens[2] found from careful experiments that summer pruning gave better results than pruning during the dormant season; by means of summer pruning he was able to induce fruitfulness on ten-year-old apple trees which had previously borne very little fruit. Goumy[3] states that the buds on very vigorous trees may be transformed into fruit buds by defoliation, that is, the removal of the supporting leaves from certain buds, but not all the buds on the branch; however, he considers this operation very limited in its application, and not to be recommended as a general practice (l. c., p. 223).

Fruit growers in England have practiced summer pruning for a long time. The experience of both practical fruit growers and scientists was given some years ago,[4] and the consensus of opinion was that summer pruning was uncertain in its effects, depending upon soil, climate, varieties of fruit and time of the operation, that specific objects might be accomplished by the process, but that the operation was of doubtful practicability.

Fall pruning.—Plat C. These trees showed no marked increase in fruit bud development. They did, however, set a fair crop of fruit and at harvest time yielded a very good amount of fruit; their shoot growth was decidedly above that for the check trees, as might have been expected this year. These trees carried heavy foliage through the season. Although fall pruning did not decrease the development of fruit buds the following year as appeared to be the case with spring pruning, still no marked increase in fruit bud development was produced in comparison with the check trees.

SERIES II. SPRING PRUNING ACCOMPANIED BY ROOT PRUNING AT DIFFERENT SEASONS.

Spring pruning accompanied by root pruning at the beginning of sap flow.—Plat A. There was a marked increase in the formation of fruit buds on the trees in this plat compared with trees in the check plats; but there

[1] Journ. Agr. and Ind. South Australia 3: 368-378. 1899.
[2] Kan. State Agr. College Exp. Sta. Bul. 136: p. 181. 1906.
[3] Goumy, E. Recherches sur les bourgeons des arbres fruitiers. Ann. Sci. Nat. Bot., (Paris). geSerie 1:135-246. 1905.
[4] The Summer Pruning of Fruit Trees. Jour. Roy. Hort. Soc. 33, Part 2: 487-499. 1908. (This article includes papers read at the Scientific Committee meeting, October 15, 1907, by the following gentlemen: H. Somers Rivers, Spencer Pickering, A. H. Pearson, F. W. Moore, Smith, F. J. Baker, Chas. Foster, and C. Wakely.)

was a poor set of fruit and the scanty crop of fruit was composed of small apples which were inferior in quality. The trees in this plat made poor growth during the season, falling below the check trees in this regard. The leaves were small and pale in color; it was estimated that the leaf area on these trees was 20 percent, compared with the foliage of the check trees as a standard. The severe root pruning of last year, which greatly restricted the root system, together with the prolonged drought of this year, produced conditions which rendered it impossible for these trees to secure sufficient water for wood growth and the proper setting and development of the fruit. Consequently the majority of the fruit buds which developed and unfolded, later fell from the trees. There is nothing gained by having a heavy bloom which later falls from the trees without setting fruit. On the contrary it is a distinct loss. The problem of the practical fruit grower is to know how to induce the formation of fruit buds which will set and develop a crop of fruit. The conditions of this experiment were such that the interference with the growth processes of the tree inhibited the normal functions of the tree.

The Duke of Bedford and Pickering[1] carried out experiments on root pruning dwarf apple trees. These investigators noted that root pruning checked the growth of trees, and might have value as a corrective for too vigorous growth and as a means of inducing fruitfulness.

Spring pruning accompanied by root pruning at the time the foliage had attained full development.—Plat B. The trees in this plat showed a decided stimulation in development of fruit buds, compared with the check trees. But relatively few fruits set, and at the harvest the fruits were few and small. The growth of the trees was poor; their leaves were small and of a pale color, with an estimated foliage area about 5 percent compared to that of the check trees. The trees suffered during the drought more than those whose roots were not pruned.

Spring pruning accompanied by root pruning at the time the fruit buds began to form.—Plat C. The trees in this plat showed uniform stimulation in the development of fruit buds as compared with check trees. However, the set of fruit was small and a light crop of inferior fruit was harvested. The growth of the trees was poor; comparing Table 6 with Table 2, it may be seen that there was no increase in circumference of the tree trunk, but a decrease of one-tenth of an inch on the average is shown, which may be taken to mean that there was no growth. The same condition was met with in plat A of Series III. The leaves were small and pale, and were estimated at 10 percent compared with the check trees.

[1] 2d Rpt. Woburn Exp. Fruit Farm for 1900, pp. 155-159.

SERIES III. ROOT PRUNING WITHOUT ANY PRUNING OF THE TREE TOPS.

There is no necessity to enter into a detailed discussion of the results secured in the three plats of this series. The trees in the three plats of this series showed marked stimulation in fruit bud formation, the main difference being that the stimulation was greater in the plats of Series III than in the plats of Series II. There is some indication that root pruning was more effective when done the latter part of May and the latter part of June than in early spring at the time growth was resumed in the trees. The larger number of fruit buds which developed on the trees in Series III as

Fig. 7.—View of check trees and trees which were root pruned without spring pruning. The check trees (left, the tree in foreground is IV C 1) carry heavy foliage and light crop of fruit. The root pruned trees (right, the tree in the foreground is III C 1) carry very sparse foliage and heavy crop of fruit. Photo August 31, 1914.

compared with Series II may be accounted for in part at least by the fact that the unpruned trees of Series III had more wood and larger fruit bearing capacity than the spring pruned trees of Series II; but after careful comparison of the trees as they stood in bloom it was convincing to the observer that there was still a difference between the two series which was produced by the tendency which the spring pruning of Series II had to discourage the development of fruit buds. The wood growth of the trees in Series III was below normal as represented by the check trees; the set of fruit was very poor in comparison with the promise held out by the heavy bloom; the fruit at harvest was undersized; and the leaf area on the

trees in Plats A, B and C was estimated at 10, 5 and 8 percent, respectively, the leaves being small and pale in color. Here the system of root pruning adopted was too severe for such a dry season. The devitalizing effects of the operation on the tree was so great that it overcame any beneficial effects in stimulating the formation of fruit buds.

SERIES IV. CHECK TREES. NO PRUNING.

The trees in the check series were not pruned last year. This year they produced a light crop of fruit buds, with no high degree of uniformity as regards the different trees. There was a light set of fruit on the check trees, and a light crop of fruit was harvested. The trees made uniform, slow growth, and carried a good crop of dense, green foliage during the summer.

SERIES V. SPRING PRUNING ACCOMPANIED BY RINGING.

The trees in the three plats of this series showed very little, if any, effect from ringing the trees at different seasons after spring pruning had been performed. The formation of fruit buds was not noticeably stimulated, being about the same as in case of the check trees. The amount of fruit set and the quantity harvested was not essentially different from that of the check trees, and the wood growth was about the same as normal. The trees in this series carried dense, green foliage through the growing season, equal to that of the check trees. It seems clear that the influence of spring pruning in discouraging the formation of fruit buds was sufficient to overcome any stimulative effect which otherwise might have been derived from ringing.

An experiment was performed by Maryland[1] on ringing crab-apple trees to induce fruitfulness. He found that ringing or girdling increased fruitfulness, but he considered this operation as a measure which could be applied only under special conditions.

The experiments of Sablon[2] have a bearing on the physiological effects of ringing. This investigator ringed pear and other trees on February 9th and May 8th, and determined the amount of reserve carbohydrates carried by these ringed trees in their roots, stems and leaves respectively, at different times until December 1st, in comparison with trees not ringed. He showed that in the beginning of spring the current of reserve material is from the roots towards the branches; from the end of May to the end of October the current of elaborated sap is from the leaves and branches towards the roots.

[1] Mass. Hatch Exp. Sta. Bul. 1: 12-13. 1888.
[2] Sablon, Leclerc du, Sur les effets de la decortication annulaire. Compt. Rend. Acad. Sci. Paris) 140: 1553-1555. 1905.

Hedrick[1] and his assistants have reported on ringing tomatoes and chrysanthemums. The results of their experiments were not favorable to the operation as applied to these plants. In the case of tomatoes there was a loss in fruit production and in the leaf and root systems of the plants, and likewise the chrysanthemum plants suffered.

Fig. 8.—View of trees in stripping and ringing experiments. On the left is VII C and on the right is VI C. The trees in both series have good, vigorous foliage. The trees appearing in series VI carry the heavier crop of fruit. Photo August 31, 1914.

Paddock[2] carried out experiments on ringing grape vines. The process generally hastened maturity of the fruit, depending upon season, variety, and condition of the vine. On the whole the operation was devitalizing and care was required in its application.

The most recent work on ringing which has come to the attention of the writer is an article by Howe[3] dealing with this operation as applied to apple, pear, plum and cherry trees. His results were not favorable to ringing fruit trees as a general practice for the conditions under which he worked. He found that ringing did not result always in increased fruitfulness.

[1]N. Y. Agr. Exp. Sta. Bul. 288: 193-209. 1907.
[2]N. Y. Agr. Exp. Sta. Bul. 151: 267-275. 1898.
[3]N. Y. Agr. Exp. Sta. Bul. 391: 575-584. 1914.

SERIES VI. RINGING WITHOUT TOP PRUNING.

Ringing when the sap began to flow.—Plat A. With the exception of one tree, the trees in this plat showed no increase in the formation of fruit buds. One tree, however, had a very good crop of fruit buds, which may be accounted for by the fact that the root system of this tree had been injured by crown gall, and in the spring it had to be tied to a stake to prevent it from blowing over. The evidence points to the conclusion that ringing at the time the sap was beginning to flow had no effect on the formation of fruit buds. The wounds healed before any influence was exerted; the operation was made too early.

Ringing at the time the foliage was well developed.—Plat B. The trees in this plat showed a uniformly increased development of fruit buds and a good crop of fruit was harvested. The growth of the trees was good, but the foliage of the trees was somewhat sparse, about 50 or 60 percent of that on the check trees. The wounds made by ringing healed perfectly and apparently no permanent injury was done to the tree.

Ringing when the fruit buds began to form.—Plat C. The trees in this plat showed stimulation in the formation of fruit buds resulting from ringing at this time. There was a fair set of fruit and a fair crop was harvested from these trees. The normal growth of the trees was not seriously interfered with. The leaf area on the trees was somewhat reduced, being about 75 percent of normal. The wounds made by ringing did not heal thoroughly.

The results of these experiments on dwarf apple trees together with other data now available on the subject show that ringing will under certain conditions increase the formation of fruit buds. The conditions required for uniform and consistent stimulation to fruitfulness are not known well enough for the formulation of a rule of practice. The physiological principle involved is not entirely clear. Klebs[1] has shown that the fruiting habit in certain plants may be influenced by changes in the environment, such as the concentration of the nutrient medium, temperature and light. The operation of ringing produces some changes in the composition of the cell sap, as previously noted in the work of Sablon. It may be that this change in the cell sap reacts upon the organs of the tree, causing a stimulation of fruit bud formation.

SERIES VII. SPRING PRUNING ACCOMPANIED BY STRIPPING.

This series requires no detailed discussion. The trees in the three plats show no increase in the formation of fruit buds resulting from stripping after spring pruning had been performed. The tendency of spring prun-

[1] Klebs, Georg. Alterations in the Development and Forms of Plants as a Result of Environment. Proc. Roy. Soc. Lond. 82: 547-558. 1910.

ing to discourage the formation of fruit buds offset any tendency which the process of stripping might have exerted in stimulating the formation of fruit buds.

Fig. 9.—The tree on the left (IV B g) is typical for check trees and carries very little fruit. The tree on the right (V C i) was spring pruned and ringed and now carries a heavy crop of fruit. Photos August 31, 1914.

SERIES VIII. STRIPPING WITHOUT SPRING PRUNING.

Where there was no spring pruning, stripping at three periods, namely, when the sap began to flow, when the foliage was well developed, and when the fruit buds began to form produced in all cases stimulation in the formation of fruit buds. The buds were strong and set a good crop of fruit, which produced at the harvest fruit of good size and quality. The growth

of the trees was normal. The trees carried dense, green foliage through the summer. There appeared to be little difference in the results of treatments applied at different times. The wounds made by stripping healed rapidly and in favorable seasons the healing is perfect. If the stripping is delayed until late summer, the healing is not so good.

The removal of strips of bark from the tree trunks does less injury to the tree than ringing, and the former gives promise of greater utility in practice than the latter.

SUMMARY.

This article deals with experiments made for the purpose of studying the effects of pruning, root pruning, ringing and stripping at different seasons of the year on the formation of fruit buds on dwarf apple trees. The observations extended over two years.

Spring pruning of the branches of the trees at the time of growth resumption had a tendency to discourage the formation of fruit buds, but there was apparent stimulation of wood growth in the trees.

Summer pruning of the branches of the trees the latter part of June, when fruit buds normally begin to show differentiation, checked wood growth the year in which the summer pruning was done, and greatly stimulated the formation of fruit buds, as was shown by the bloom and crop of fruit the following year.

Fall pruning of the branches of the trees in November did not materially influence the crop of fruit buds, but caused vigorous wood growth the following year.

Severe root pruning at the time of growth resumption in the spring (April 23d), at the time the leaves were well developed (May 31st), and at the beginning of fruit bud differentiation (June 23d) when accompanied by or preceded by spring pruning of the branches, produced some stimulation in fruit bud formation. Another series of experiments showed that the spring pruning did much to offset the effects of the root pruning. The root pruning treatment retarded wood growth in the current and succeeding year; the leaf area of the trees was reduced and the trees showed injury from the treatment.

Root pruning on April 23d, at the resumption of growth in the absence of spring pruning, did not give as much stimulation to fruit bud formation as the same treatment applied at later dates. Apparently this was too early for the full effects to be felt by the trees. Root pruning when the foliage was fully developed, and when the fruit buds began to become differentiated, in the absence of spring pruning of the tops, produced very marked stimulation in fruit bud formation. At these three times the treat-

ment retarded wood growth and foliage development in the current and succeeding year, and the trees suffered from the treatment.

Ringing at different seasons when accompanied by or preceded by spring pruning of the branches produced no noticeable stimulation of fruit bud formation.

Ringing at the time growth was resumed in the absence of spring pruning, did not stimulate fruit bud formation. The treatment was given too early. Ringing at the time the foliage was fully developed in the absence of spring pruning gave the best results; however, when the treatment was given at the time the fruit buds began to become differentiated, there was some stimulation to fruit bud development.

Stripping at different seasons when accompanied by or preceded by spring pruning, had no stimulative effect on fruit bud formation. The effects of stripping were offset by those of spring pruning. Stripping at the three seasons already mentioned, in the absence of spring pruning, stimulated fruit bud formation uniformly.

There is not yet enough known about the operation of root pruning, ringing and stripping for the formulation of rules by which practical fruit growers may utilize advantageously in their orchards root pruning, ringing and stripping to increase the fruitfulness of the trees.

THE EFFECT OF GREEN MANURING ON SOIL NITRATES UNDER GREENHOUSE CONDITIONS.

By HARRY H. HILL.*

The effect of green manure as a soil improver depends upon a number of conditions. On account of our limited knowledge in regard to the decomposition of such substances in the soil it is impossible to give rules whereby the greatest efficiency can be obtained.

It is well known that the decay of organic matter, as clover and grasses, may either be beneficial or harmful to the succeeding crop. The result depends to a great extent upon four factors: the type of organism bringing about decomposition, the chemical and physical properties of the soil, and the time element. The beneficial effects of green manuring are generally stated as follows:

1. The greatest amount of plant food is utilized.
2. Leaching or destructive decomposition is prevented.
3. The bacterial flora of green manure is very effective in causing desirable chemical changes.
4. The texture of heavy clay soils is improved by the addition of organic matter.
5. The plant food constituents are rendered available slowly and thus furnish food continuously throughout the growing season.

The harmful effects of green manures are generally stated as follows:

1. The physical condition of the soil may be injured for plant growth. It becomes too loose and open, decomposition is decreased and leaching increased.
2. In the presence of much moisture, decomposition takes place too rapidly.
3. An acid condition of the soil may be brought about and thus plant growth retarded.

It is a well established fact in farm practice that green manuring is an important means for restoring soil fertility. This subject has great economic importance and a further investigation of this important subject is needed.

One of the essential elements required for the restoration of depleted soils and an increase crop yield is nitrogen. Nitrogen is our most expensive plant food, so if we can increase the store of this element by other means than the purchase of nitrogenous materials, it is true economy.

*This problem was outlined by W. B. Ellett and E. B. Fred. The author wishes to acknowledge the help and assistance of these men. Due credit is given Dr. E. B. Fred of the University of Wisconsin and W. G. Harris of this department for some of the bacteriological and chemical work done on the experiments conducted during 1911-12.

It is believed by a large number of investigators that of all the nitrogenous bodies found in soils, nitrates are the most readily available, and it is to the accumulation of nitrates in soils under a green manure treatment that this paper is concerned.

Koch (1) found that a soil kept for nine months under proper moisture and temperature conditions showed an increase of 3.38 milligrams of nitrate nitrogen. During the next eleven months, an increase of only 1.39 milligrams was shown.

Fred (2) in his study on "Nitrification in Certain Types of Virginia Soil" has found that a greater increase in nitrates is shown for Virginia soils when kept in a protected condition than was recorded by Koch. He found the maximum increase using a soil from Appomattox County, and the minimum with a Valley type of soil from Blacksburg, Virginia.

Commenting on these results, the author says: "When calculated as percent of the total nitrogen of the different soil types, this gain becomes even more striking." After giving the amounts of accumulated nitrates in each of the leading soil types, he says: "These figures show that a large percent of total nitrogen of these various soil types is nitrified, when the soils are kept moist and protected from leaching. In the unprotected series (pots with open bottoms), the reverse is true. After one year there is little change in the nitrate content. There is perhaps less present than at the beginning. About 1 milligram is the average amount of nitrate nitrogen present in 100 grams of Virginia soil. From the above data it will be seen that by protection from leaching this amount may be increased six to ten times, according to the type of soil."

From the above results it can be seen that Virginia soils are capable of a decided nitrate development under protected conditions—so it will be interesting to see to what extent this nitrate accumulation may be stimulated when the soil is subjected to a green manure treatment.

Review of Previous Investigations.

It is very apparent in going over the literature of research relating to the effect of organic matter when incorporated with the soil, that scientific effort has been directed to a greater degree toward the chemical than the bacteriological side of the subject. In the light of modern research we know that the latter phase of the subject is of great importance, for it is to the bacteria of the soil that we look for aid, in order that the proper decomposition of these organic materials may be brought about, so that the plant may derive a benefit therefrom.

Brown (3) investigating the effect of crop rotation on the activities of soil bacteria found that a continuous cropping to corn or clover gave an increase in soil bacteria. The three-year rotation of corn, oats and clover

gave higher soil counts than a two-year rotation of corn and oats. Green manures did not always increase the bacterial count of the soil. It was suggested that probably the moisture factor or the incorporation of large amounts of organic matter with the soil might furnish an explanation for this fact.

B. Heinze (4) on contrasting stall and green manures found that the latter carried but few organisms which would break down the insoluble material. The decomposition of green manure was found to be due to dust organisms and those found in soil. For this reason the number and kind of organisms in a given soil were found to determine to a great degree the effect of green manure on succeeding crops. Decomposition was very rapid in an open sandy soil rich in bacteria and relatively slow in a soil poor in bacteria. In an open sandy soil the nitrogen of the green manure may pass over into nitrates and be washed out, while in a heavier soil the nitrogen was found to become more slowly available and not washed out so soon. For this reason, in heavy soils, green manures often give the best results the second year.

Koch (5) thinks the good effects produced when green manure is added to stable manure may be due to an increased nitrogen fixation by Azotobacter, the organism using the cellulose of the manure as a source of energy.

In another paper, Koch (6) states that green manure interferes with the germination of cotton seed, but not with clover, corn and wheat.

Lemmerman and Tazneko (7) experimenting with a sandy soil, noted a slight loss of nitrogen, perhaps as ammonnia, when green manure was turned under. The authors believe that the proportion of crude fibre in green manures is indirectly proportional to the soluble nitrogen. This is perhaps the reason why many think that straw decreases the nitrogen in the soil.

Laurent (8) attributes the harmful effect of green manure to large amounts of organic acids, as well as changes brought about in the texture of the soil.

Lipman and Brown (9) observed a retarding ammonification when sugar was present. This effect was not so marked in the case of starch and cellulose.

A. Muntz (10) considers the value of green manures proportional to the rapidity with which their nitrogen is converted into nitric nitrogen. This investigator compared the value of green lupines, dried blood, and sulphate of ammonia. The increase in nitrates where lupines were employed was attributed to better aeration.

Neale (11) noted a marked gain in the yield of corn when crimson clover was used as a green manure. He believed the nitrogen thus applied to be much more economical than when nitrate of soda is used.

Patterson and Scott (12), investigating the influence of certain soil constituents upon nitrification, found that green manures, such as starch and sugar, retarded nitrification.

Pfeiffer (13), in his studies of the nitrogen assimilating bacteria, found that open sandy soils gave the best results when green manures were applied. This same author (14) noted a harmful effect when straw was used as a green manuring crop.

Baessler (15), studying the value of lupines, serradella, crimson clover and hairy vetch for green manures on humus sandy soils, advised turning under as late as possible in the life of the plants and not in the hot summer when the plants are green.

Bredemann (16) found that the addition of organic matter, such as hay and sugar, produced a harmful effect the first year, and the next year a beneficial effect was noted.

Causmann (17) observed larger yields with rye on light sandy soils when green lupines were turned under late in September.

Delwiche (18) investigating the effect of green manures on sandy soils, found that cowpeas, hairy vetch, soy beans and crimson clover are best adapted to this type of soil.

Ehrenberg (19) found that the addition of stall manure at the same time with green manure, to be unwise, as a too rapid decomposition ensued. There was a washing away of the valuable fertilizing constituents. He states that straw will retard a too rapid nitrification.

Engberding (20), studying the effect of straw and sugar upon the total number of bacteria in the soil, found at first an increase in the bacterial count followed by a decrease. The ammonifying and nitrogen fixing groups of bacteria showed an increase, while the nitrifying group was retarded.

Fischer (21), in his paper on the changes that nitrogen undergoes in sandy and clay soils, offers an explanation for the loss of nitrates in a soil to which carbohydrates have been added in the following reaction:

$$24\ NaNO_3 + 5\ C_6H_{12}O_6 = 24\ NaOH + 12\ N_2 + 30\ CO_2 + 18\ H_2O.$$

Frankfurt and Duschechkin (22) state that green manure, under field conditions, caused a diminution of the nitrate content. Both legumes and non-legumes showed this effect. He offered as an explanation the moisture changes of the soil.

There seems to be a great variation in opinion as to the effect of organic matter, in the soil, on nitrate formation. Conn (23), in his work, "Agricultural Bacteriology," says: "The building of nitrates will not take place in the soil so long as there is any considerable amount of organic material or any considerable amount of free ammonia present. If there is much

organic material rapidly decomposing so as to produce ammonia, this will completely check the formation of nitrates, for these nitrifying bacteria will not grow in the presence of either organic material or ammonia. It is not until after decomposition has been completed and practically all the organic compounds used up that the nitrifying germs can begin to act."

Marshall (24), commenting on these earlier views, believes, " The exact relation of organic matter in the soil to the activities of nitrifying bacteria is but beginning to be properly understood. Earlier observation made it manifest that heavy applications of animal manures, or green manure, may not only retard nitrification but may actually cause the disappearance of a part, or of all of the nitrate in the soil. Subsequent experiments by Winogradski and Omelianski showed that in pure cultures the presence of even slight amounts of soluble organic matter may depress or even suppress the development of the nitrifying bacteria. It was, therefore, concluded by these authors that relatively small amounts of soluble organic matter may inhibit nitrification. These conclusions, based on the study of liquid cultures only, were given a very broad application by many writers on agricultural topics. More recent experiments make it certain, however, that in the soil itself small amounts of soluble matter, e. g., dextrose, are not only harmless but may really stimulate nitrification. It was shown, likewise, that humus and extracts of humus may, under suitable conditions, stimulate nitrification to a very striking extent."

Stevens and Withers (25) give two reasons why the activity of nitrifying organisms, in pure culture under laboratory conditions, cannot be compared with their activities under conditions in the field. First, " In mixed culture their symbolic and physiologic relations are so different from those obtained in pure cultures that their metabolic processes are with difficulty expressed," and second, " The presence of large amounts of solid matter, sand or earth, in contact with the liquid medium, so alters its relation to the nitrifying organisms that their physiologic activities and metabolic products are different."

These authors say in conclusion: " In the light of the facts set forth, the direct application of Winogradski's conclusions to the field must be abandoned and with them any practices based upon them, and the activities of these soil bacteria must, in the future, be studied more largely under their natural environments."

PRELIMINARY EXPERIMENTS CONDUCTED IN 1911.

In the fall of 1911 pot experiments were carried out to study the effect of plant tissue on nitrate formation in partially sterilized and unsterilized soil. For this purpose one-gallon glazed pots with 5 kilos. each of Blacksburg soil were used. The organic matter was added as indicated in Table I.

The partial sterilization was effected by heating the soil in a large drum sterilizer, such as is used in the sterilization of milk cans in creamery practice. In this way the whole soil series was treated at the same time. The soils were heated for two hours at a steam pressure of five pounds. While we know that this treatment does not thoroughly sterilize the soil, it does reduce the number of micro-organisms to an enormous extent. After heating, the pots were allowed to stand in the greenhouse unprotected from dust for three months.

From time to time water was added to maintain a moisture content of 18 percent. For this, ordinary tap water was used. In order to maintain a thorough aeration, the pots were worked every two weeks.

It is reasonable to assume from the results of Seelhorst, Lemmermann, Koch and others that plant tissue will bring about various changes in the soil. Perhaps one of the most marked changes to be noted is its effect on the soluble nitrogen of the soil. Bearing this fact in mind, the soil nitrates were determined at the end of the experiment.

On reviewing the results in Table I, it will be seen that after the soils had remained in the greenhouse for three months an increase in nitrates was observed in every case, and in soils receiving certain treatments this increase was marked. The soil originally contained about 1 milligram of nitrate nitrogen in each 100 grams of soil.

TABLE I.—*Nitrate Content in Blacksburg Soil Treated with Organic Matter.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil	
		Unsterilized	Sterilized
1	Control	1.92	5.09
2	Control	1.81	5.47
3	4 percent paper	1.69	2.26
4	4 percent paper	1.98	2.97
5	4 percent straw	2.31	2.10
6	4 percent straw	1.81	2.61
7	8 percent straw	2.12	2.09
8	8 percent straw	2.15	2.44
9	4 percent blue-grass	8.82	9.83
10	4 percent blue-grass	8.44	10.51
11	4 percent red clover	5.84	3.08
12	4 percent red clover	4.46	2.06
13	4 percent alfalfa	2.10	5.71
14	4 percent alfalfa	3.86	3.64

It will be seen that in each case, except with clover, the sterilized series contained more nitrate at the time of this analysis than the unsterilized. This may be accounted for in many ways; partial sterilization probably brought about changes in the plant tissue which made it more soluble. The

types of bacteria after sterilization are also very different from the original flora, as shown by Russell, Hutchinson and others. The ammonifiers seem to predominate in a partially sterilized soil (according to the Rothamsted work because of the destruction of the protozoa) and in the presence of nitrifiers this form of nitrogen readily passes over into nitrates.

The highest amounts of nitrates were obtained in the soils receiving a blue-grass treatment, red clover and alfalfa being next in order. Straw did not show any marked effect on nitrate formation, still it did not cause an appreciable decrease in this form of nitrogen, as has been claimed by some investigators. For this treatment, the nitrates in the sterilized series were about the same as in the unsterilized soils.

From the results given in Table I it is very evident that organic matter such as blue-grass, clover and alfalfa, when turned under in the soil, tend to pass over into the nitrate form of nitrogen. The results of this preliminary experiment justify a closer study of the subject. With this end in view, a more elaborate series of experiments concerning the decomposition of organic matter in the soil was planned.

OUTLINE OF EXPERIMENTS DURING 1912 AND 1913.

The investigational work to be presented in this paper includes both laboratory and pot experiments, and other experiments are now under way, leading, if possible, to a duplication of these results under field conditions. The plan of the work included in this paper is as follows:

Laboratory Study.—Periodic nitrate determinations and bacterial counts to test the effect of the addition of organic substances on the number of bacteria as well as their activity in the soil.

The nitrates were determined by the Reduction Method, using 5 grams reduced iron and 10 grams zinc dust in an alkaline solution. The nitrates were extracted by shaking 500 grams of soil with 1000 c. c. of water, and allowing to stand two hours, with occasional shaking, before filtering.

The bacterial counts were made on Heyden-Nährstoff agar by dissolving 7.5 grams of the Heyden-Nährstoff in 200 c. c. of cold water and 12.5 grams of ordinary agar in 800 c. c. of water. The Heyden-Nährstoff was heated on the water bath until clear and the precipitate had settled. The solution was then filtered, mixed with the agar, and sterilized in the autoclave.

Greenhouse Study.—Pot experiments were run parallel to the laboratory experiments to study the effect of organic materials on the growth of higher plants.

It is natural to assume that the behavior of such substances as paper, straw, clover, beans and blue-grass in soils of various origin and texture will be very different, and for this reason each soil type will be discussed separately.

PREPARATION OF THE SOIL SAMPLES.

Five of the leading Virginia soil types were used in these experiments. These soils ranged in texture from sandy loams to heavy clays. The green manures were added in the proportions given in Table II.

TABLE II.—*Plan of Treatment.*

1.—Control.		
2.—0.3	percent	paper.
3.—0.6	"	straw.
4.—0.44	"	clover.
5.—0.44	"	soy beans.
6.—0.22	"	blue-grass.

The green materials were chopped up to about one-half inch in length and thoroughly mixed with the dry soil. The soil was then placed in pots, the water content raised to about one-half saturation and allowed to remain in the greenhouse at summer temperature. In every case, except paper and straw, green plants were used. They were first dug, using care not to break the roots. The roots were then washed until all the soil was removed. The calculations for the addition of the green materials, with the exception of paper, were made on the basis of results obtained in ordinary farm practice. If green manure crops were turned under, a maximum yield would be about as follows: Straw, 8 tons per acre; clover, 6 tons; soy beans, 6 tons, and blue-grass, 3 tons. The paper was added at the rate of 4 tons per acre. The pots used were 15 kilos. capacity, and the green materials were calculated for this amount of soil.

The Swedish filter paper used in these experiments represents about the purest form of cellulose that can be easily obtained. Treating green manuring substances as impure forms of cellulose, containing nitrogen and small amounts of mineral matter, there is a possibility that some insight may be obtained as to the action of these so-called impure forms when incorporated with the soil. In order to investigate this question in an intelligent manner, the action of cellulose in a pure form had to be studied.

When straw is used as a green manure, some beneficial effects may be obtained from the plant food contained in the straw and beneficial effects have been noticed. Still the increase in plant growth may have been due to a physical betterment of the soil, due to the introduction of this material. It was probably made more open and porous, therefore it is hoped that the experiments to follow will give some indication as to the effect of pure cellulose in the soil, be it beneficial or harmful.

In the case of stable manure there is an enormous increase in the number of bacteria in soils to which it is applied. With these forms of organic matter it will no doubt be quite different, because, unlike the stable manure, these substances do not carry as many bacteria. The decomposition of such organic substances is brought about by the bacteria already present in the soil, or else by those forms attached to dust particles on the green manures.

There are many other factors intimately concerned with the changes which organic substances undergo in the soil, such as temperature, water and air. This last named factor, aeration, plays an important part as shown by the results of various workers. In sandy soils organic substances break down much more rapidly than in the more compact clay types. This is largely due to a better aeration characteristic of sandy soils.

Experiments Conducted with Albemarle Soil.

This soil is known as Cecil clay and is widely distributed in the Piedmont section of Virginia. It is a heavy clay, underlain by a heavy clay subsoil, characterized by quartz sand scattered through it. This soil is derived from igneous and metamorphic rocks, fragments of which are often found on the surface. The sample of soil used in these experiments came from near Crozet, Virginia.

According to the plan previously outlined bacterial counts were made as shown in Table III and nitrate determinations at regular intervals. These data are given in Table IV. Crops were also grown on these soils to determine the effect of green manures on plant growth.

TABLE III.—*Number of Bacteria in Albemarle Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil				
		After 4 weeks	After 12 weeks	After 16 weeks	After 20 weeks	After 30 weeks
1	Control	6,619,000	2,433,000	1,707,000	1,000,600	2,056,039
2	Paper	5,059,600	3,607,000	2,361,000	1,480,908	1,693,434
3	Straw	5,665,500	4,716,000	3,707,000	1,721,032	2,005,145
4	Clover	22,522,900	3,416,000	2,036,000	1,921,152	2,136,157
5	Beans	11,006,500	6,040,000	1,129,000	3,001,800	1,614,228
6	Blue-grass	....	1,886,000	1,930,000	1,320,792	1,118,934

The greatest increase in number of bacteria takes place the first month after the green manures are applied. The increase in some cases is enormous, especially is this true of clover and beans. Paper gave no marked effect. Unfortunately the blue-grass count for this month was lost. After

three months the increase in number was not so noticeable, and from that time until the end of the experiment, there was very little difference between the controls and treated pots.

A review of the figures in Table III shows that nitrogenous green manures as clover and beans greatly increase the number of bacteria in the soil. Paper and straw show this effect to a less marked degree.

EFFECT ON THE NITRATE CONTENT OF ALBEMARLE SOIL.

From the results of the preliminary experiments it is very probable that the legumes and blue-grass (nitrogen holding substances) soon bring about a great increase in nitrates. The Albemarle soil used in these experiments is very compact, not well aerated, and in previous tests showed very little power to nitrify. This would indicate that if the proper moisture and temperature conditions were maintained, nitrogenous organic matter, when turned under in the soil, would slowly change to a soluble form as nitrate. The answer to this question may be seen in Table IV.

TABLE IV.—*The Accumulation of Nitrates in Albemarle Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	0.59	0.74	0.55	1.25	1.50	3.51	2.65
2	Paper	0.59	......	......	trace	trace	0.20	1.29
3	Straw	0.59	......	......	1.81	2.20	3.18	3.70
4	Clover	0.59	1.22	2.01	2.40	2.00	3.62	3.82
5	Beans	0.59	0.86	1.14	1.79	2.00	3.03	2.97
6	Blue-grass	0.59	0.80	0.82	1.27	1.20	2.02	2.21

From Table IV it will be seen that even after 20 weeks there is hardly any appreciable change in the nitrate content of the soil. After 24 weeks those soils to which nitrogenous substances were added contained much more nitrate nitrogen than the check pot. In the case of straw there is very little difference, but where paper was added there was a marked decrease in the amount of nitrate nitrogen. The destruction of nitrates after paper is added to the soil has been reported by many investigators. Some claim that it is due to denitrification, although total nitrogen analyses do not indicate any loss in nitrogen. Probably the paper furnishes a very suitable medium for the growth of the organisms that convert nitrates into albumen. In this transformation there is not any loss in total nitrogen, and in an

ordinary nitrifying soil these albuminous compounds soon change to nitrates. Straw seems to have somewhat the same effect as paper, but to a much less degree. As seen from the figures of Table IV green manures in Albemarle soil, except paper, after a few weeks, increased the nitrate content. As compared with the increase in number of bacteria this is very small.

From the results of previous tests it would seem that the green manures, other than paper, would exert a beneficial effect on plant development. With this in view, three parallel series of pots, fertilized as indicated in the above experiments, were planted with buckwheat, oats and corn. The green manures were added three to four months before planting in order that the organic matter might have time to be broken down and rendered more available to plants. When ripe these crops were cut and weighed. The green and dry weights are given in Table V.

TABLE V.—*Weight of Crops Grown on Albemarle Soil.*

Pot No.	Treatment	Weight of Crop in Grams.					
		Buckwheat		Oats		Corn	
		green	dry	green	dry	green	dry
1	Control	10	1.5	11	4.2	75	17
2	Paper	2	0.5	7	2.8	41	8.5
3	Straw	4	1.0	13	5.5	121	26.5
4	Clover	6	1.5	12	4.7	90	20
5	Beans	7	2.0	20	7.3	122	23
6	Blue-grass	3	1.0	11	5.5	99	17

The beneficial effect of green manures on higher plant growth is clearly seen in this table. With the exception of paper, there is in almost every case a decided increase in growth when the various forms of plant tissue are turned under. This is most apparent with the soil receiving the bean treatment. The oat and corn series show the effect of green manures on plant growth better than the buckwheat series. The depressing effect of paper is shown in each group. Although the different crops show some fluctuation in growth, on the whole, the treatment with green manures had about the same effect on each crop.

The results of the experiments with Albemarle soil show that nitrogenous substances in the form of green manures increased the number and activity of the lower as well as the higher plants. Paper and straw retard the activities of certain groups of soil bacteria (nitrifiers), and hand in hand with this is the development of higher plants.

Experiments Conducted with Appomattox Chocolate Soil.

This soil belongs to the Cecil series, but is a much heavier clay than the Albemarle sample. It is a residual soil derived from micaceous schist and gneiss rocks. This soil is well adapted to general farming and tobacco. The sample for these experiments came from the district sub-station at Appomattox, Virginia.

The bacterial counts, nitrate determinations and plant growth tests were made with this, as described for Albemarle soil.

TABLE VI.—*Number of Bacteria in Appomattox Chocolate Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil				
		After 4 weeks	After 12 weeks	After 16 weeks	After 20 weeks	After 30 weeks
1	Control	15,413,800	3,006,000	1,108,000	2,321,000	1,311,000
2	Paper	8,470,800	2,625,000	3,707,000	2,961,000	1,991,000
3	Straw	13,280,300	2,654,000	2,875,000	4,322,000	3,746,000
4	Clover	22,559,800	2,151,000	1,050,000	4,242,000	2,801,000
5	Beans	18,509,100	6,347,000	1,935,000	2,081,000	4,663,000
6	Blue-grass	16,791,100	5,079,000	1,746,000	1,681,000	2,727,000

The first count, made 4 weeks after the green manures were added shows a decrease in the case of paper and an increase in all of the other treated soils. This is very marked in the case of clover and beans. After 12 to 16 weeks no very marked difference was seen.

EFFECT ON THE NITRATE CONTENT OF APPOMATTOX CHOCOLATE SOIL.

With this soil, as with Albemarle soil, it is probable that the nitrogenous green manures will cause a great increase in nitrates. As noted in the annual report of this station for 1911-12, Appomattox Chocolate soil is a much better nitrifier than the Albemarle soil and for this reason should show a greater and more rapid increase in nitrates than the other soil type. The course of nitrate formation is shown in Table VII.

TABLE VII.—*The Accumulation of Nitrates in Appomattox Chocolate Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil: At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	1.21	...	1.40	1.44	2.40	2.24	2.22
2	Paper	1.21	0.86	...	...	trace	0.27	1.09
3	Straw	1.21	2.16	1.27	3.53	6.6	5.30	4.01
4	Clover	1.21	2.76	2.12	7.24	...	4.28	5.36
5	Beans	1.21	2.50	1.60	3.03	2.02	3.06	4.00
6	Blue-grass	1.21	2.76	1.96	2.12	2.8	2.65	3.60

A great increase in nitrates occurred, as was expected. After 28 weeks the control pot doubled its nitrate content. The pot receiving a treatment of paper did not give any marked increase in nitrates. On the other hand straw showed a gradual increase. From these figures it will be seen that green manures, with the exception of paper, exert a very beneficial effect on nitrate formation in this soil.

TABLE VIII.—*Weight of Crops Grown on Appomattox Chocolate Soil.*

Pot No.	Treatment	Weight of Crop in Grams. Buckwheat: green	Buckwheat: dry	Oats: green	Oats: dry	Corn: green	Corn: dry
1	Control	3	1.0	23	7.5	69	17.2
2	Paper	4	1.0	12	4.0	51	10.0
3	Straw	5	1.0	26	10.3	109	22.0
4	Clover	5	1.5	22	9.5	113	22.5
5	Beans	6	1.5	30	12.0	121	22.0
6	Blue-grass	7	1.2	23	7.0	105	19.5

It will be seen from the table above that in each case paper caused a diminution in plant growth, while the other forms of organic matter showed a beneficial effect. Beans and clover as green manures proved especially good for the growth of corn and buckwheat. With oats the effect is not so marked. Taken in their entirety the results with Appomattox Chocolate soil agree very closely with those obtained from the Albemarle soil, and go to prove that organic matter increases the number and activity of the lower and higher plants. The growth of buckwheat on this soil was poor.

Experiments Conducted with Appomattox Light Soil.

This soil is known as the Cecil sandy loam. It is gray or brownish gray in color, fine to medium in texture and ranging in depth from four to fourteen inches. This soil is residual, and is derived from mica and talcose schists. It is probably the most widely distributed type in this section. This soil is well adapted to general farm crops and heavy export tobacco. This sample also came from the district sub-station at Appomattox, Virginia.

TABLE IX.—*Number of Bacteria in Appomattox Light Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil				
		After 4 weeks	After 12 weeks	After 16 weeks	After 20 weeks	After 30 weeks
1	Control	10,146,400	6,070,000	2,041,000	1,600,960	1,713,121
2	Paper	13,559,200	7,828,000	3,301,000	2,641,584	2,704,210
3	Straw	14,339,100	9,520,000	1,814,000	7,844,704	4,782,310
4	Clover	17,845,900	6,582,000	1,815,000	3,081,848	2,837,130
5	Beans	20,555,300	3,943,000	2,030,000	4,442,664	5,251,124
6	Blue-grass	14,579,200	2,662,000	1,386,000	2,281,368	2,807,107

From the bacterial count made at the end of 4 weeks, it can be seen that a very pronounced increase in numbers is shown as a result of fertilizing with green manures. This is greatest in the case of the legumes. For some unexplained reason these counts showed wide variations from time to time, and in contrast to the counts from other soil types this increase continues and may be seen at the end of 20 weeks.

EFFECT ON THE NITRATE CONTENT OF APPOMATTOX LIGHT SOIL.

In 12 weeks from the date green manures were added there is a distinct gain in nitrates, except where paper was added. The maximum amount was found in the case of beans at the end of 24 weeks. After this time the nitrates began to decrease slightly.

TABLE X.—*The Accumulation of Nitrates in Appomattox Light Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil: At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	2.95	2.53	2.74	5.51	5.20	4.67	5.65
2	Paper	2.95	0.37	0.40	0.74	1.32	2.17	3.80
3	Straw	2.95	3.32	2.78	5.16	...	6.52	6.89
4	Clover	2.95	3.28	2.89	9.38	5.63	6.14	6.37
5	Beans	2.95	2.34	2.28	11.25	4.19	4.41	5.19
6	Blue-grass	2.95	2.18	2.0	3.69	6.20	4.27	5.31

The paper did not entirely destroy all traces of nitrates as in the former tests, and after 32 weeks the harmful effect had apparently passed off. This indicates that in open sandy soils the same amount of green manures exert a much more beneficial effect on plant growth than in the compact clay soils.

TABLE XI.—*Weight of Crops Grown on Appomattox Light Soil.*

Pot No.	Treatment	Weight of Crop in Grams. Buckwheat green	Buckwheat dry	Oats green	Oats dry	Corn green	Corn dry
1	Control	3.0	2.0	31	12	108	19.0
2	Paper	3.0	0.5	28	11	129	28.0
3	Straw	12.5	3.2	35	13.8	138	28.0
4	Clover	8.5	2.3	36	16.8	170	34.3
5	Beans	13.5	3.8	43	18.7	177	37.0
6	Blue-grass	5.0	1.5	34	14	105	19.0

A glance at the figures in Table XI shows that in each case, with the exception of paper, a decided beneficial effect is given by the addition of green manures. The pots receiving treatments of beans and clover gave the highest crop yield.

Experiments Conducted with Blacksburg Soil.

This soil is called the Hagerstown silt loam and is gray to brownish gray in color, containing some fine sand. It is derived by the weathering of the Cambro-ordovician limestone. This soil forms broad tracts of excellent farming land which is well adapted to general farm crops and is especially noted for its blue-grass.

TABLE XII.—*Number of Bacteria in Blacksburg Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil				
		After 4 weeks	After 12 weeks	After 16 weeks	After 20 weeks	After 30 weeks
1	Control	7,741,000	7,229,000	1,930,000	3,922,352	1,646,694
2	Paper	7,088,000	5,341,000	1,815,000	3,402,040	2,675,519
3	Straw	15,430,000	5,755,000	3,583,000	4,242,544	4,572,326
4	Clover	11,540,000	6,371,000	2,102,000	5,163,095	5,170,759
5	Beans	6,714,000	8,348,000	4,314,000	2,761,545	5,213,796
6	Blue-grass	5,860,000	6,418,000	2,006,000	2,161,296	3,381,434

The bacterial counts in this soil type showed a marked increase during the first month of the experiment. This was followed by a gradual decline in numbers, until the control and the pots receiving a green manure treatment contained about the same number of organisms. This was also found to be true with the Albemarle soil.

EFFECT ON THE NITRATE CONTENT OF BLACKSBURG SOIL.

Taken as a whole, the addition of organic materials to this soil caused a decided increase in nitrate production. The blue-grass pots gave variable results. In some cases, this treatment caused a decrease below the control.

The pot receiving a treatment of paper gave negative results for nitrates, even after 32 weeks. There was a slight amount of nitrate present when the soil in this pot was tested at the end of 40 weeks.

TABLE XIII.—*The Accumulation of Nitrates in Blacksburg Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	0.82	1.32	1.06	2.35	3.20	2.03	5.24
2	Paper	0.82	0.53	—	—	trace	—	2.39
3	Straw	0.82	1.13	0.88	1.85	3.20	2.30	3.27
4	Clover	0.82	1.46	1.56	2.71	5.40	2.99	4.74
5	Beans	0.82	1.39	1.23	3.70	4.00	2.44	4.67
6	Blue-grass	0.82	1.19	1.49	2.31	2.60	1.89	5.46

The greatest amount of nitrate formation occurred in the pots receiving treatments of beans and clover. At the end of 40 weeks the control pot showed a slight increase over all the other treatments except blue-grass.

Paper produced a harmful effect on the formation of nitrates during a greater portion of the experimental period. At the end of 40 weeks this injurious effect was not so marked.

This soil type is more open and porous than the clay soils from Albemarle and Appomattox counties, and on account of this physical difference it is probable that green manure will have a much better effect on plant growth. The figures in Table XIV answer this question.

TABLE XIV.—*Weight of Crops Grown on Blacksburg Soil.*

Pot No.	Treatment	Weight of Crop in Grams.					
		Buckwheat		Oats		Corn	
		green	dry	green	dry	green	dry
1	Control	21	5.7	22	11.8	109	30.5
2	Paper	7	1.2	25	8.0	78	12.0
3	Straw	36	10.5	34	16.3	151	38.5
4	Clover	16	4.5	37	18.5	176	48.5
5	Beans	13	3.7	25	11.5	138	40.5
6	Blue-grass	25	6.7	30	15.8	131	34.3

In every case, except where paper was added, green manuring substances gave an increase in yield. This varies from a slight difference to double that of the control.

Experiments Conducted with Norfolk Soil.

This soil is classified as Norfolk fine sandy loam. This is the most extensive trucking soil in this section of the State. This type is derived from sedimentary deposits that have undergone the process of weathering. The sample selected for this study came from the Virginia Truck Experiment Station, Norfolk, Virginia.

TABLE XV.—*Number of Bacteria in Norfolk Soil.*

No. Pot	Treatment	Number of Bacteria per gram of dry soil				
		After 4 weeks	After 12 weeks	After 16 weeks	After 20 weeks	After 30 weeks
1	Control	4,819,000	2,696,000	1,741,000	1,881,128	1,681,000
2	Paper	5,972,000	5,200,000	1,669,000	2,001,200	1,830,948
3	Straw	16,810,000	5,150,000	3,618,000	1,881,128	2,387,962
4	Clover	10,910,000	3,882,000	3,573,000	1,681,008	2,401,429
5	Beans	13,730,000	7,573,000	2,730,000	1,721,032	3,075,551
6	Blue-grass	5,247,000	4,931,000	3,222,000	1,600,960	3,826,626

Table XV shows that in every case, an application of green manure caused an increase in soil bacteria. The greatest increase resulted from an application of straw. Because of the very open porous nature of this soil, it is certain that aeration is good, and under such conditions we would naturally expect organic matter to break down very rapidly. Paper exerted a suppressing effect on the soil bacteria throughout the greater portion of the experimental period.

EFFECT ON THE NITRATE CONTENT OF NORFOLK SOIL.

By careful observation it will be seen that the rate of nitrate formation in this soil type was quite similar to that of Blacksburg soil.

TABLE XVI.—*The Accumulation of Nitrates in Norfolk Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	0.93	1.65	1.24	2.93	3.60	3.12	4.29
2	Paper	0.93	0.53	.....	.....	trace	0.13	2.94
3	Straw	0.93	1.91	1.45	2.55	.....	4.54	5.32
4	Clover	0.93	2.64	2.4	4.45	3.38	4.74	6.59
5	Beans	0.93	1.65	1.50	3.35	5.00	3.8	3.45
6	Blue-grass	0.93	1.64	1.39	4.07	5.00	3.17	2.01

The legumes, clover and beans, gave the highest amounts of nitrate nitrogen with this soil type. Paper depressed nitrate formation during almost the entire experimental period. After 40 weeks this substance did not show the depressing effect so manifest at the beginning of the experiment.

Plant growth in this series, was greatly stimulated by the addition of green manures. The increase in growth due to the addition of straw, beans, clover and blue-grass was enormous. In every case the addition of paper gave much smaller yields than the control pots.

TABLE XVII.—*Weight of Crops Grown on Norfolk Soil.*

Pot No.	Treatment	Weight of Crop in Grams.					
		Buckwheat		Oats		Corn	
		green	dry	green	dry	green	dry
1	Control	26	5.5	43	17.8	184	47.8
2	Paper	19	4.5	24	9.8	109	23.5
3	Straw	20	5.7	35	14.5	204	54.3
4	Clover	23	5.5	35	14.5	221	60.0
5	Beans	16	3.5	34	13.0	220	60.8
6	Blue-grass	20	4.7	35	16.5	196	57.8

EXPERIMENTAL WORK CONDUCTED IN 1913-1914.

The experimental data resulting from the investigations conducted during the years 1911-12 proved to be so interesting that it was deemed best to duplicate the work, with certain modifications.

In the preceding investigations one set of pots was used for the chemical and bacteriological studies, while two sets, with the same additions of organic matter, were devoted to vegetation experiments. One set of the vegetation pots in this (1913-14) series received the same quantities of organic matter, while to a second was added double the quantity of green manure, keeping in mind the calculations for the former experiments, which, as stated, were based on the maximum yields obtained in general farm practice. The pots for the chemical and bacteriological work were kept at a moisture content of 18 percent, as near as possible, throughout the period of experiment. Moisture determinations were made the first of each month, and water added to bring the soils to the above moisture content.

The colorimetric phenol di-sulphonic acid method was used for the determination of nitrates until a concentration of 9 milligrams was reached. This has been found (26) to be very satisfactory until the concentration goes beyond this. For greater amounts of nitrate, the zinc-iron reduction method was used. For bacterial counts the same medium was used, and the same general procedure followed as in the first year's work.

Corn was the only crop used in these experiments and was planted in March. In two weeks the corn had reached a height of two inches. Where double the quantity of organic matter was added the initial growth appeared to be more rapid than those pots under the ordinary treatment. At this stage all the treatments showed a uniform growth. During the third week all of the pots to which paper had been added began to show a yellowish appearance. This was very pronounced in the pots to which a double treatment of paper had been given.

Experiments Conducted with Albemarle Soil.

The soil used in these experiments was Cecil clay, representing the same type used in the preceding studies. This soil came from the farm of Mr. H. H. Brown, near Crozet, Virginia. It was very poor in soluble nitrogen and was well suited for experiments of this nature.

TABLE XVIII.—*Number of Bacteria in Albemarle Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil			
		After 20 weeks	After 30 weeks	After 40 weeks	After 50 weeks
1	Control	3,122,607	3,246,792	3,124,836	2,461,065
2	Paper	1,415,599	1,561,482	1,406,700	2,656,223
3	Straw	3,666,339	3,746,480	3,679,368	2,846,474
4	Clover	3,684,383	3,896,482	3,872,492	2,441,921
5	Beans	4,403,797	4,564,890	4,487,172	2,762,218
6	Blue-grass	3,371,308	3,496,870	3,371,189	2,166,709

It was shown by the results obtained in 1911-12 that very high bacterial numbers were obtained when counts were made four weeks after the addition of the green nitrogenous materials. Some of these counts ran as high as 22,559,800 bacteria per gram of dry soil. This was shown to be true with the Appomattox Chocolate with an addition of clover. As a rule, this is not the case with virgin soils and may be due to the introduction of bacteria found on the organic matter that was incorporated with the soil. Bearing this in mind, the soil organisms were allowed to adapt themselves to these new conditions before counting was begun.

Albemarle soil showed that the addition of green manure increased the number of soil organisms through 40 weeks. After this an equilibrium appeared to be established. Paper suppressed the number through this period, but on standing 50 weeks the injurious effect of this material appeared to pass off. Straw also gave a beneficial effect. This was more pronounced than blue-grass.

TABLE XIX.—*The Accumulation of Nitrates in Albemarle Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	trace	0.48	1.11	1.13	1.30	2.25	3.06
2	Paper	trace	trace	trace	trace	trace	trace	trace
3	Straw	trace	0.64	1.73	1.82	1.96	2.50	4.09
4	Clover	trace	0.84	2.37	2.42	2.78	4.16	7.95
5	Beans	trace	0.68	2.25	2.29	2.99	3.64	5.08
6	Blue-grass	trace	0.96	2.27	3.00	3.14	3.22	4.36

The formation of nitrate nitrogen in the Albemarle soil for the different soil treatments, with the exception of paper, progressed at about the same rate for the first 12 weeks. After that time there was a steady formation. The greatest amount of nitrate was found in the pots to which clover had been used as a green manure. The pots receiving soy beans and blue-grass developed nitrate at about the same rate, the former treatment showing slightly higher figures. The average for the several treatments was 5.37 milligrams against 3.06 for the check. Paper suppressed nitrate formation throughout the experiment, as there was only a trace after 40 weeks. In this connection it may be interesting to note analyses of plants from check and paper pots.

Two pots were set up, holding 15 kilos. of Blacksburg soil, and planted to corn. The check pot grew to maturity while the pot receiving paper gave plants that were very yellow and decidedly stunted in growth. The yellow appearance was manifest from the time the plants were an inch in height. The whole plant was weighed and analyzed in each case.

Weights and Analyses.

Pot No.	Treatment	Dry weight	Milligrams Nitrogen
1	Paper	3.5 grams	315.0
2	Check	26.2 grams	490.0

These results are very interesting and are worthy of further study, for it appears that the paper has some effect on retarding the storing of nitrogen in plant tissue.

TABLE XX.—*Weight of Crops Grown on Albemarle Soil.*

Pot No.	Treatment	Weight of Crop in grams.			
		Corn, regular application		Corn, double application	
		green	dry	green	dry
1	Control	184	106.0	130	85.0
2	Paper	138	86.0	112	78.5
3	Straw	210	112.0	180	98.0
4	Clover	167	93.0	181	90.5
5	Beans	203	99.5	191	111.0
6	Blue-grass	200	104.5	212	110.5

The crop yields for Albemarle soil, taken as a whole, are somewhat higher than in 1911-12. However, the effect of green manures is probably not so great. Where double the quantity of organic matter was applied, there was no increase in yield except where beans and blue-grass were used. Paper showed a depressing effect throughout. This is especially noticeable in the double application.

The yields and effect of organic materials would not be expected to be very large in pot culture with this soil type, for decomposition seems to proceed slower than in some of the other soils. Experience has shown this soil to be very unsatisfactory for pot experimentation, on account of its tendency to bake.

Experiments Conducted with Appomattox Chocolate Soil.

The soil used in these experiments was Cecil clay. This soil was decidedly poor in soluble nitrogen, as only very slight traces were found after shaking the soil with water and allowing to stand for two hours. This sample of soil was from Appomattox, Virginia, and is well suited for experiments in green manuring on account of its deficiency in organic matter. Indications are that this type of soil can be wonderfully improved by the addition of such materials.

TABLE XXI.—*Number of Bacteria in Appomattox Chocolate Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil			
		After 20 weeks	After 30 weeks	After 40 weeks	After 50 weeks
1	Control	1,142,684	1,324,728	1,314,718	1,832,411
2	Paper	1,240,578	1,286,942	1,246,720	1,307,819
3	Straw	992,561	1,346,791	1,399,846	1,562,789
4	Clover	1,459,161	1,987,496	2,086,913	2,839,721
5	Beans	2,527,153	2,861,470	2,689,470	2,461,389
6	Blue-grass	1,912,182	2,817,618	2,547,618	2,289,761

After the first 20 weeks all the pots receiving green manures gave counts greater than the check pots. Paper depressed the number below any of the other treatments, with the exception of straw, which dropped below paper at the first count. After this the straw appears to stimulate bacterial growth. At the end of the 50-week period the legume and blue-grass pots gave practically the same numbers.

TABLE XXII.—*The Accumulation of Nitrates in Appomattox Chocolate Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	trace	0.16	0.61	0.64	0.71	0.93	1.32
2	Paper	trace	trace	trace	trace	trace	trace	trace
3	Straw	trace	0.17	0.63	0.64	0.76	0.98	2.00
4	Clover	trace	0.17	0.62	0.71	0.84	1.25	2.34
5	Beans	trace	0.17	0.64	0.92	0.99	1.60	2.96
6	Blue-grass	trace	0.17	0.62	0.87	1.00	1.46	2.47

A beneficial effect from the use of green manures when applied to Appomattox Chocolate soil is shown throughout the above series.

At first sight the effect may not appear so marked as in the experiments conducted in 1911-12, but when we consider the fact that the original soil contained only a trace of nitrate nitrogen and the soil used the first year contained 1.21 milligrams, the accumulation of nitrates is shown to be equally as great. In every instance organic nitrogenous materials gave higher results than the check pots. The pots treated with soy beans gave

the highest returns. Paper was detrimental to the formation of nitrates, as only traces were found at the end of 40 weeks. The results with blue-grass were very satisfactory and in every case gave higher amounts of nitrate nitrogen than clover. There is a possibility that decomposition progressed more rapidly with the non-legume than with the legume, as indications point to this, the blue-grass being devoid of tough woody stems, and easy to reduce to a fine state of division.

TABLE XXIII.—*Weight of Crops Grown on Appomattox Chocolate Soil.*

Pc No.	Treatment	Weight of Crop in grams.			
		Corn, regular application		Corn, double application	
		green	dry	green	dry
1	Control	99	75.5	73	70
2	Paper	70	68.0	71	68
3	Straw	130	80.5	112	80
4	Clover	109	76.0	140	87
5	Beans	122	80.0	134	89
6	Blue-grass	188	99.5	150	91

The increase in crop yields for Appomattox Chocolate soil is very marked in all pots receiving a treatment of green manures. Paper depresses growth both with single and double applications of organic matter, while the blue-grass again stimulates growth in a very marked way.

The double application of green manure gave no increase, with the exception of clover and beans, and this was very slight. The returns from straw were very good.

Experiments Conducted with Appomattox Light Soil.

The soil for this study represented the Cecil sandy loam type of soil and came from the same general locality as the sample used in the preceding experiments with this soil type. The sample was fine textured and contained fine particles of talc and mica. From a chemical point of view, the soil was poor in organic matter. Especially was this true of the nitrates, as there were only very slight amounts of this substance. This sample was sent by Mr. B. G. Anderson of Appomattox, Virginia.

TABLE XXIV.—*Number of Bacteria in Appomattox Light Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil			
		After 20 weeks	After 30 weeks	After 40 weeks	After 50 weeks
1	Control	3,167,781	3,195,863	3,243,222	2,358,764
2	Paper	2,794,831	2,841,962	2,641,946	2,146,789
3	Straw	4,936,841	4,862,113	4,642,318	4,050,994
4	Clover	4,394,434	4,519,863	4,613,114	3,555,495
5	Beans	5,196,473	5,004,719	4,746,191	4,416,096
6	Blue-grass	4,209,070	4,319,716	4,218,160	3,076,068

From the above table it can be seen that green manures, when added to Appomattox Light soil have a very marked effect on the number of soil organisms. Through the entire experimental period, with one exception, these additions of organic matter gave counts higher than those of the check pot. The pot receiving an application of soy beans gave the highest number of organisms. In all cases paper suppressed bacterial development below the other treatments. For the first 40 weeks there was very little variation in numbers from a treatment of green manure. After this period the variations are more marked.

TABLE XXV.—*The Accumulation of Nitrates in Appomattox Light Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	trace	0.22	0.28	0.36	0.91	1.48	2.12
2	Paper	trace	trace	trace	trace	trace	trace	trace
3	Straw	trace	0.22	0.34	0.81	0.96	1.63	3.21
4	Clover	trace	0.64	0.82	0.99	1.46	2.12	3.54
5	Beans	trace	0.24	0.48	0.96	1.18	2.31	3.92
6	Blue-grass	trace	0.28	0.94	1.25	2.00	2.60	3.51

From the results given above it can be seen that in every case green manures gave higher amounts of nitrates than the check pot. The rate of nitrate formation is probably not as great as in the preceding year. Still when final analyses were made, taking into consideration that Appomattox Light soil in 1911-12 contained initial nitrate to the extent of 2.95 milligrams, the increase is equally as great. The effect of organic matter is manifest after 12 weeks. From that time on the quantity of nitrate increased more

rapidly. The legume treatment gave the highest results. The straw and blue-grass pots were almost as good. Where paper was added only traces of nitrate nitrogen were found.

TABLE XXVI.—*Weight of Crops Grown on Appomattox Light Soil.*

Pot No.	Treatment	Weight of Crop in grams.			
		Corn, regular application		Corn, double application	
		green	dry	green	dry
1	Control	174	101	154	90
2	Paper	135	86	110	78.5
3	Straw	240	123	88	75
4	Clover	225	110	176	94
5	Beans	218	110	213	102.5
6	Blue-grass	236	126	207	111.5

The figures above show that organic materials with the exception of paper have benefited plant growth. There was no increase in crop weights from a double application of the green materials. The blue-grass results are good in both series. This is probably due to its more rapid decomposition. The depressing effect of paper is manifest to a marked degree with both applications of green manure. Crop yields were much larger than in the experiments conducted during the preceding years.

Experiments Conducted with Blacksburg Soil.

The soil selected for this work represented a typical Hagerstown silt loam and came from an unfertilized plat that had been in corn for six years. The soil was practically exhausted as far as nitrate nitrogen was concerned, for on analysis it showed only 0.6 milligrams of nitrogen in each 100 grams of soil. A soil containing such a small amount of this substance gives an ideal medium, when enriched with green materials, for the study of nitrate accumulation.

TABLE XXVII.—*Number of Bacteria in Blacksburg Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil			
		After 20 weeks	After 30 weeks	After 40 weeks	After 50 weeks
1	Control	1,922,829	1,954,472	2,631,792	2,813,797
2	Paper	1,280,614	1,346,825	2,671,342	2,913,884
3	Straw	3,412,625	3,496,574	3,876,476	4,006,425
4	Clover	4,957,363	4,979,893	4,914,769	3,890,882
5	Beans	4,943,484	4,736,484	4,618,462	3,966,939
6	Blue-grass	4,160,028	4,281,465	4,098,767	4,047,615

After 20 weeks all pots containing Blacksburg soil with a treatment of green manure showed an increase in bacterial numbers. Clover gave the highest counts, with beans next in order. Blue-grass and straw gave the lowest numbers for the green manure treated pots, blue-grass being best. Toward the end of the experimental period there was a decided increase in the straw pot, so that at the end of 50 weeks this pot contained about the same number of bacteria as the pot receiving the blue-grass application.

Paper depressed numbers, but as the experiment progressed this was not so marked. By referring to the above table it will be seen that there was a slight increase from week to week. At the end of 50 weeks the pot treated with paper gave a count slightly higher than the check, showing that the injurious effect was gradually passing off. From the above it will be seen that green manures were very beneficial in increasing the number of bacteria in this soil type.

TABLE XXVIII.—*The Accumulation of Nitrates in Blacksburg Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	trace	0.60	0.76	0.90	1.12	2.46	3.77
2	Paper	trace	trace	trace	trace	trace	trace	trace
3	Straw	trace	1.16	1.24	1.68	2.25	3.18	4.94
4	Clover	trace	1.12	1.40	1.86	2.15	3.45	6.29
5	Beans	trace	0.88	1.60	1.99	2.30	3.41	5.64
6	Blue-grass	trace	1.12	1.80	2.15	2.47	3.13	4.70

The accumulation of nitrates in the Blacksburg soil is very marked. Results with this soil in 1911-12 gave it a rank of 100 as based on nitrate

accumulation. The above results as compared with the other soils gave it a rank of 58, taking the soil highest in nitrate production as 100. Apparently this is quite a drop; however, this rank gives it second place in nitrate accumulation. Green manures in every case gave increased amounts of nitrate nitrogen. Paper as usual prevented the formation, as only traces were found after 40 weeks.

TABLE XXIX.—*Weight of Crops Grown on Blacksburg Soil.*

Pot No.	Treatment	Weight of Crop in grams.			
		Corn, regular application		Corn, double application	
		green	dry	green	dry
1	Control	262	122.5	138	99
2	Paper	172	100.5	90	77
3	Straw	329	153	207	113
4	Clover	217	115.5	211	109
5	Beans	286	139	217	121
6	Blue-grass	282.5	135	214	118.5

Experiments Conducted with Norfolk Soil.

The soil used in these experiments is classified as Norfolk fine sandy loam. It was an open textured soil containing grains of coarse quartz sand. This sample was furnished the department by Mr. T. C. Johnson of the Virginia Truck Experiment Station, Norfolk, Virginia.

On analysis this soil showed only very slight traces of nitrate nitrogen, and served the purpose admirably, as it was shown in the experiments of 1911-12 that this soil could be materially increased in soluble nitrogen by the addition of green manures.

TABLE XXX.—*Number of Bacteria in Norfolk Soil.*

Pot No.	Treatment	Number of Bacteria per gram of dry soil			
		After 20 weeks	After 30 weeks	After 40 weeks	After 50 weeks
1	Control	3,472,581	3,561,792	3,796,418	3,956,484
2	Paper	2,100,029	2,125,418	2,196,718	3,349,812
3	Straw	5,202,254	5,146,171	5,346,096	5,411,424
4	Clover	6,000,974	5,849,782	5,196,418	4,598,003
5	Beans	4,307,155	4,472,436	4,994,869	5,278,363
6	Blue-grass	5,596,234	5,327,863	4,996,418	4,859,483

In each case where green manure was applied the Norfolk soil gave counts greatly exceeding the check pot. This was also true with nitrate accumulation, while plant growth was as good as any soil type used in these experiments. From a bacteriological point of view this soil is an excellent one, and its bacteriological efficiency may be greatly enhanced if subjected to a green manure treatment.

The counts for the paper treated pot were much higher than in the other types of soil. This soil is more open and the decomposition of the paper progressed at a more rapid rate than in the clay soils. Its effect on plant growth was not as marked as in some of the other soils, which goes to show that this injurious effect passes off if there is sufficient aeration of the soil.

TABLE XXXI.—*The Accumulation of Nitrates in Norfolk Soil.*

Pot No.	Treatment	Milligrams of Nitrate Nitrogen per 100 grams of dry soil						
		At beginning	After 12 weeks	After 20 weeks	After 24 weeks	After 28 weeks	After 32 weeks	After 40 weeks
1	Control	trace	1.24	1.32	1.56	3.29	4.27	6.46
2	Paper	trace	0.40	0.82	0.89	1.20	1.53	2.20
3	Straw	trace	1.80	2.15	2.36	3.40	4.51	8.88
4	Clover	trace	2.00	2.52	3.14	4.61	7.20	10.94
5	Beans	trace	1.80	2.96	3.47	4.18	8.69	11.01
6	Blue-grass	trace	1.72	2.46	2.94	4.00	6.47	11.90

The returns from the addition of green manures were greatest with the Norfolk soil. The formation of nitrates was more pronounced at the end of the 12-week period than in any other of the soil types. In every case, the addition of green materials gave much higher yields in nitrate nitrogen than did the check pot. Paper did not give the suppressing effect that was so marked in the other soils. This is probably due to its rapid decomposition in this open type of soil.

TABLE XXXII.—*Weight of Crops Grown on Norfolk Soil.*

Pot No.	Treatment	Weight of Crop in grams.			
		Corn, regular application		Corn, double application	
		green	dry	green	dry
1	Control	220	109	170	108
2	Paper	236	110.5	167	94
3	Straw	284	134	221	117
4	Clover	270	132.5	199	108
5	Beans	270	127	240	123
6	Blue-grass	299	140	178	105

Green manures proved very beneficial when applied to the Norfolk soil. By comparing these results with those obtained with Blacksburg soil, it will be seen that these two soil types give figures that agree very closely. Plant growth was much better on these soils than on the heavy clay soils from Albemarle and Appomattox counties. Paper apparently had no marked effect on plant growth. A double application of green manure did not give increased yields.

EFFECT OF NATURE OF SOIL ON NITRATE FORMATION.

It has been shown that the five leading types of Virginia soil increase their nitrate content to a marked extent if kept under the proper conditions of temperature and moisture, under glass. This power to form nitrates is greatly increased when green manures are incorporated with these soils.

From results obtained along this line it would appear that there is some one soil type among the number which stands out more prominent than the others as a producer of nitrate nitrogen. In order to see if this be true, the results on the check pots recorded in this paper have been compared with similar results obtained by Fred (27) at an earlier date.

Fred, working with untreated soils representing the same types used in this paper, found that there was a gradual increase in nitrate on standing a year under greenhouse conditions. The first section of Table XXXIII gives results taken from his work, while the other two sections are from this paper.

The entire table of results is on untreated pots from the five leading types of Virginia soil, kept under greenhouse conditions.

A rank of 100 has been given to the soil showing the greatest nitrate accumulating power, the others rank according to their respective amounts of accumulated nitrate.

TABLE XXXIII.—*Effect of Nature of Soil on Nitrate Formation.*

FRED'S RESULTS.

Soil type	Nitrates at beginning	Nitrates at end	Increase	Rank based on nitrate accumulation
Appomattox Chocolate	1.02	10.7	9.68	100
Albemarle	0.78	9.4	8.62	89
Norfolk	2.10	9.0	6.10	63
Appomattox Light	0.45	6.5	6.05	62
Blacksburg	0.70	6.7	6.00	61
RESULTS IN 1911-12				
Blacksburg	0.82	5.24	4.42	100
Norfolk	0.93	4.29	3.36	76
Appomattox Light	2.95	5.65	2.70	61
Albermarle	0.59	2.65	2.06	46
Appomattox Chocolate	1.21	2.22	1.01	22
RESULTS IN 1913-14				
Norfolk	trace	6.46	6.46	100
Blacksburg	trace	3.77	3.77	58
Albemarle	trace	3.06	3.06	47
Appomattox Light	trace	2.12	2.12	32
Appomattox Chocolate	trace	1.32	1.32	20

On examination, the results contained in the above table show a variation in nitrate accumulation.

The Appomattox Chocolate soil gives for Fred a rank of 100, and in the experiments conducted in 1911-12, 1913-14, an average rank of 21.

Albemarle soil gives for Fred a rank of 89 and in the experiments from 1911 to 1914 an average of 46.5.

Norfolk soil gives for Fred a rank of 63 and in these experiments an average of 88.

Appomattox Light soil gives for Fred a rank of 62 and in these experiments an average of 46.5.

Blacksburg soil gives for Fred a rank of 61 and in these experiments an average of 79.

It will be seen from these results that a certain soil type will not have the power to accumulate nitrates to as marked degree at one time as at another. In other words, to establish its rank and hold it. Soils taken from field to greenhouse, from the same type of soil, will often show wide variations from a bacteriological point of view, and it is a known fact that soils from the same field will show great differences in nitrifying power. This is probably why Virginia soils of a same type will show variations in nitrate accumulation, therefore it is not reasonable to give a soil type a certain rank for nitrate accumulation and expect this soil to maintain it.

It is believed from the results of this paper that the open soils have a natural tendency toward nitrate accumulation, and that this may be stimulated by applications of green materials. The results obtained with the Blacksburg and Norfolk soils, both in nitrate and increased plant growth, are an indication that this is true.

SUMMARY AND CONCLUSIONS.

1.—Organic matter, as blue-grass, clover and alfalfa, when turned under in the soil, appear to pass over into nitrates. This is more marked in sterilized than in unsterilized soil.
2.—The total number of bacteria in soils treated with green manures was much greater than in those soils receiving no green manure treatment. Legumes gave in most cases the highest bacterial count.
3.—Pure cellulose in the form of Swedish filter paper caused a depression in the number of bacteria and in plant growth.
4.—The rate of nitrate formation was greatly improved by the presence of green manures.
5.—Paper in each soil type caused a depression in nitrate formation.
6.—In every case plant growth was benefited by the addition of green manures.
7.—Paper had a pronounced effect on plant growth and was the cause of the yellow appearance given to the plants.
8.—There was a smaller amount of nitrogen in plants grown in pots treated with paper than those grown on untreated soil.
9.—Soils vary in their power to accumulate nitrogen. Soils, from the same field, when taken at different times, show a variation in nitrogen accumulating power.

BIBLIOGRAPHY.

1. A. Koch—Jour. f. Landw., 1911. (Festschrift.)
2. Fred—Va. Agr. Exp. Sta. Rept., 1911-12, pp. 174-202.
3. Brown—Iowa Exp. Sta. Research Bulletin No. 6.
4. B. Heinze—Landw. Mitteil. f. d. Prov. Sachsen, 1909, pp. 169-170.
5. A. Koch—Centralbl. f. Bakt., Abt. II, 1910.
6. A. Koch—E. S. R., Vol. 28, 1913, p. 817.
7. Lemmerman and Tazenko—Landw. Jahrb., Bd. 38, 1909, pp. 101-113.
8. Laurent—Chemiker Zeitung, Report 19, 1895, p. 84.
9. Lipman and Brown—N. J. Exp. Sta. Rep't., 1908, p. 100.
10. A. Muntz—Comp. rend. T. 110, 1890, p. 972.
11. Neale—Del. Exp. Sta. Rep't, 1892, pp. 19-22.

12. Patterson and Scott—Jour. Dep't. Agr., Victoria 10, 1912.
13. Pfeiffer—Stickstoffsammelene Bakterien, Brache, und Raubbau, 1912, p. 13.
14. Pfeiffer—Landw. Insti. Breslau 4, 1909, p. 733.
15. Baessler—Wochenschr. pom. oken. Ges. 23, 1893, No. 18, pp. 227-231; No. 19, pp. 242-244.
16. Bredemann—Landw. Jahrb., Bd. 43, 1913, pp. 669-694.
17. Causmann—Deut. Landw. Presse 30, 1903, No. 31, pp. 263-264.
18. Delwiche—Wis. Exp. Sta., Bulletin No. 147, 1906, pp. 1-15, 20-24, 27-48.
19. Ehrenberg—Fuhlings Landw. Zeitung, 1910, p. 198.
20. Engberding—Centralbl. f. Bakt. II, Abt. 23, 1909, p. 601.
21. Fischer—Landw. Jahrb. 41, 1911, pp. 755-822.
22. Frankfurt and Duschechkin—Russ. Jour. Exp. Landw. 8, 1907, No. 6, pp. 707-708.
23. Conn—Agri. Bacteriology, 1901, p. 103.
24. Marshall—Microbiology, 1911, p. 261.
25. Stevens and Withers—N. C. Agr. Exp. Sta. Rep't., 1909-10, p. 51.
26. Hill—Va. Agr. Exp. Sta. Rep't., 1911-12, p. 140.
27.—Fred—Va. Agr. Exp. Sta. Rep't., 1911-12, p. 179.

SMOOTHNESS AND KEEPING QUALITIES IN ICE CREAM AS AFFECTED BY SOLIDS

By W. K. BRAINERD.

From the standpoint of the consumer, there are three essential factors in ice cream making, namely, flavor, smoothness, and keeping qualities or stability of texture. The factors controlling the flavor are essentially the same as in any other dairy product. The factors governing the smoothness and keeping qualities of ice cream are not well understood. However, it is generally conceded that outside of temperature, texture of brine and speed of freezer, factors which are well defined, the smoothness and keeping qualities depend upon the nature and amount of solids in the mixture. Previous observations on these points have been based upon conclusions drawn from the feel of cream upon the tongue, and appearance to the eye.[1] This bulletin is the result of a micro-photographic study of smoothness and its relation to stability of texture in ice cream.

Microscopic Examination of Ice Cream.—In taking this work up the first effort was directed to the making of a device by which ice cream could be held in its original form as to texture and studied under a microscope. This was accomplished most satisfactorily by using a room in which the temperature could be controlled and maintained at 35 degrees to 40 degrees F. After numerous trials the following device for a freezing stage was constructed, which proved very satisfactory. Fig. 1. A piece of iron

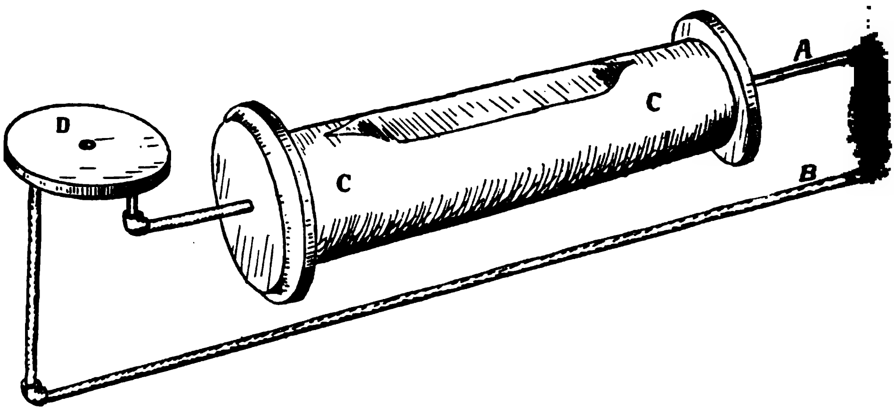


Fig 1.—Ammonia plates upon which photographs were taken. The ammonia entered in pipe A, pipe B being connected with the exhaust pump. Ice cream placed on these plates was held in the original form for an hour or more at a time, examined with the microscope and photographed.

pipe (c) three inches in diameter was flattened on one side, caps screwed upon the ends, and ammonia passed through it by tapping these caps and

[1] See bibliography, Vt. Agr. Exp. Sta., Bul., 155.

connecting to ammonia system by high pressure ammonia pipe. The circular stage (D) was made by attaching two circular iron plates, ten inches in diameter, one-half-inch apart and running a three-quarter-inch pipe through the center. This circular stage proved unsatisfactory, owing to the heat generated by the arc light.

All photographs shown were taken on the plate, or flattened surface of the iron pipe. Ice cream could be kept on this plate in its original form for an hour or more. The instrument used was a Leitz binocular stereoscopic microscope, with camera attachment.

Effect of Amount of Solids on the Smoothness of Cream.

It has been assumed by practical ice cream makers that, other things being equal, the more solids a mixture contains, such as butter fat or gelatin,

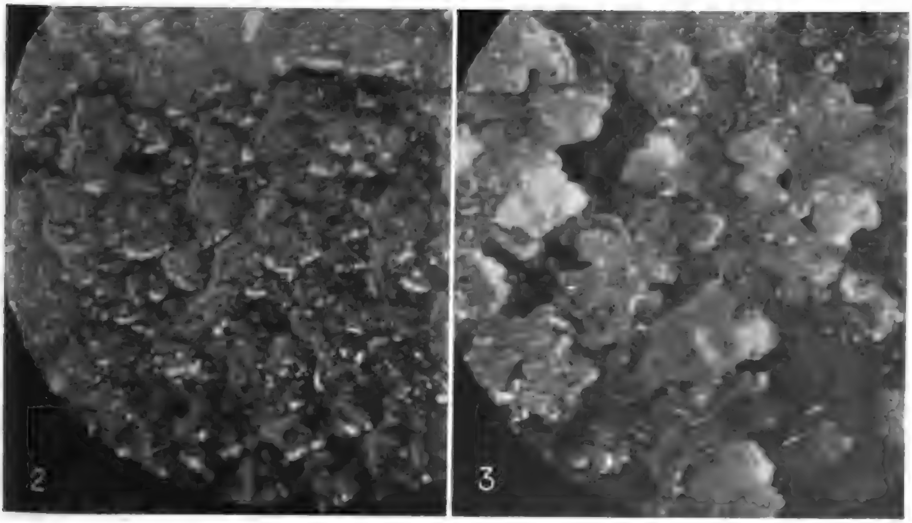


Fig. 2.—Showing ice cream made from 20 percent cream; and Fig 3.—Showing ice cream made from 10 percent cream without filler. Note the relative size of the ice crystals, those in Fig. 3 being much larger than in Fig. 2. The cream in Fig 2 is smooth while that in Fig 3 is coarse and rough. These illustrations show the effect of different amounts of solids in creams. In the cream containing the larger amount of fat, the solid particles are nearer together and the ice crystals correspondingly more numerous and smaller. In this and all other photographs of ice cream shown, conditions such as temperature of brine, speed of freezer, consistency of cream at end of freezing process, etc., are constant, the variations being only as noted.

the smoother the ice cream will be. This is very forcibly shown in Figures 2 and 3. When extreme amounts of fat or other solids are present, this rule will not apply in practical ice cream making. The general idea is that with 40 percent to 45 percent of fat present, the ice cream is not so smooth as with 20 percent of fat.

In the micro-photographs shown in this publication, the light spots are, more or less, clear ice crystals. It will be noted that they are not always distinct in definition. This is due to some difficulties encountered in making the photographs. They were made on an ammonia plate to which was attached a condensing pump. The vibration from this pump in some cases caused indistinctness in the pictures. The exposures ranged from 7 to 20 minutes. At times a slight melting of the crystals caused indistinctness. The photographs, however, show the size and form of ice formation, which are the essential points.

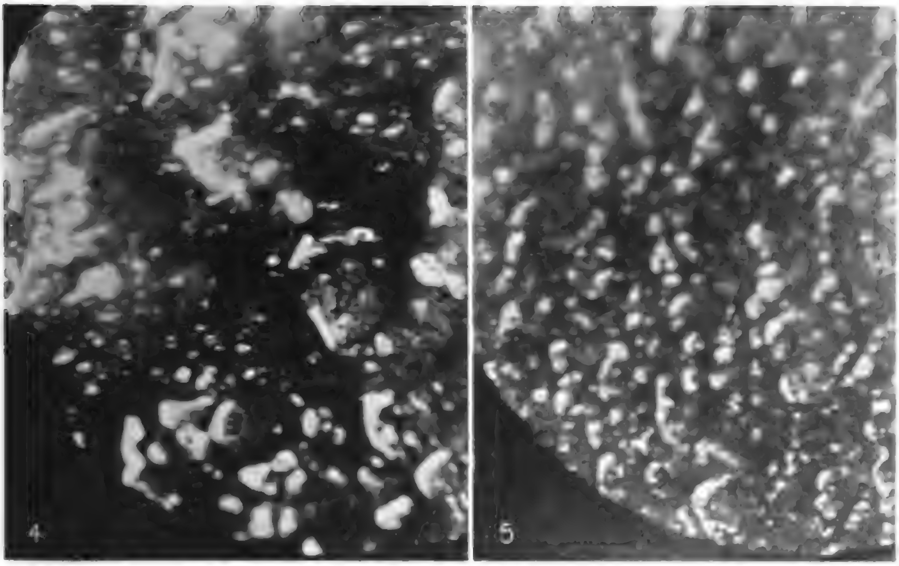
It will be noted that figure 2, 20 percent cream,[1] shows the ice in much smaller crystals and more evenly distributed than in figure 3, which contains 10 percent cream, but otherwise it was the same mixture and frozen the same as figure 2. This difference in the ice formation may be explained as follows: It is a well-defined law of crystallography that ice freezes in a regularly formed crystal, the size depending mainly upon the rapidity of freezing. The presence of a particle of solid matter in the water will naturally interfere with the formation of this crystal, and together with the agitation due to the turning of the freezer, makes the irregularly formed crystals much smaller. Hence of two lots of cream, the distances between solid particles must be less in the lot which contains the greater amounts of solids. Assuming that the homogeneity of the mixture remains constant throughout the freezing process, the space between solid particles would be less in the lot having the most solids. Inasmuch as roughness in ice cream is due to large ice crystals or ice formation, the cream having the larger amount of solids is smoother.

Fineness of Division of Solids and Smoothness of Cream.—From the standpoint of the ice cream maker, solids may be in suspension, in emulsion, colloidal solution, and in true solution.

Solids in Suspension.—At the present time in ice cream practice, solids are seldom used in the suspended form. This is on account of the lack of fineness of division. This will be more forcibly brought out later on in this discussion. Uncooked starch is probably one of the best illustrations of a solid in such form.

Emulsions.—In ice cream making the emulsions met with are of fat. The importance of fineness of division of this solid in the emulsified form is shown in figures 4 and 5. These photographs are of cream of the same composition and made in the same way in every respect, except that the cream in figure 5 was homogenized; that is, the fat globule divided into minute particles. It will be noted that the ice cream from the homogenized

[1] In all lots of cream discussed and photographed in this paper 10 c. c. per gallon of vanilla flavor was used, and 1 pound of sugar. The freezing was secured by a mixture of 1 part salt to 5 parts ice. The speed of the freezer was 60 revolutions throughout. The temperature of the brine varied to some extent, but it is believed this variation would not effect the results shown, as the contrasts are so marked. In each case in which a filler was used the cream contained 15 percent of butterfat.



Figs. 4 and 5.—Note in Fig. 4, unhomogenized cream, that the ice crystals are larger and more irregular; that the ice is not so evenly distributed. The cream of No. 5 which was homogenized was much smoother in appearance and to the tongue than No. 4.

cream is much smoother than that from the unhomogenized cream; that is, the ice crystals are smaller, more numerous and more evenly distributed. Ice cream manufacturers are taking advantage of this principle and are securing smoothness in their products by dividing the fat globule with the homogenizer.

Colloidal Solutions.—The solids most frequently found in ice cream in the shape of colloidal solutions are gelatin, gum tragacanth, cooked starch, eggs, etc. The chief difference between particles in suspension, colloidal solutions and true solutions is the fineness of division. Bigelow, writing on solution, says:

*"'We are inclined to apply the term suspension if any indication of settling is perceptible after a short time, or if we think separation will eventually take place. We include under the head of colloids, substances dispersed through a solvent in particles so fine they will not settle out, and yet not so fine but what we can, by experiment, form approximate estimates of their size.''

It will be noted that the stability of the solution depends upon fineness of the division. As is well known, ice cream is often held for several days. After the cream becomes soft two or three times and is again hardened by freezing, the solids in the mixture separate to a greater or less extent, permitting the water to re-form in large ice crystals. This causes coarseness

*Book on Theoretical and Physical Chemistry.

or roughness. The one factor therefore, in a cream of good keeping qualities, is the permanency of solution of the solids in the original sample, which in turn depends mainly upon the fineness of division of the solids present. The value of fineness of division of colloidal solutions, both as to smoothness and keeping qualities of ice cream, is forcibly illustrated in photographs shown in figures 6, 7, 8 and 9. Figures 6 and 7 are of fresh ice cream exactly alike in every respect except that 6 contains 1 ounce of

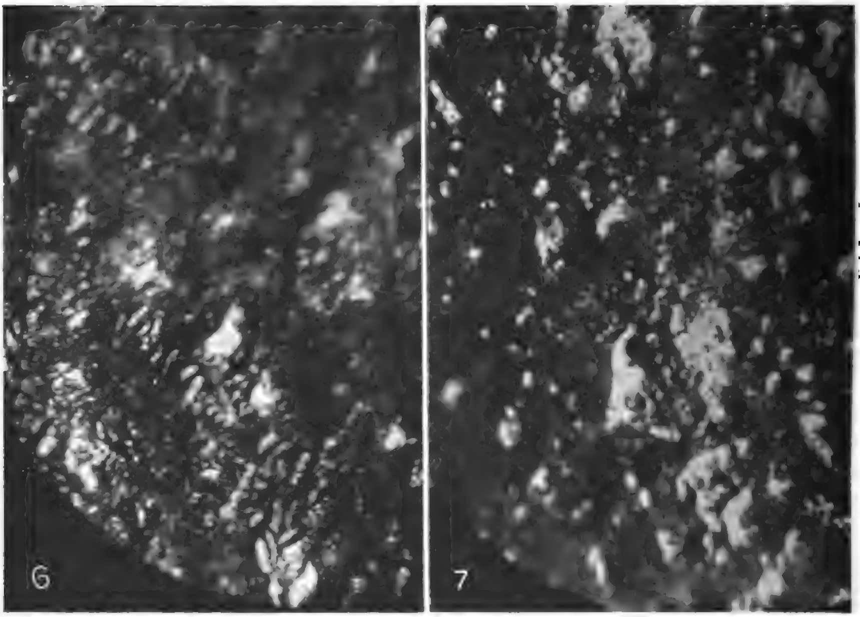


Fig. 6.—Cream containing one ounce of gelatin per gallon and Fig 7 cream containing one ounce cooked starch per gallon. Note that the ice crystals in the starch cream are larger and not so evenly distributed as in the gelatin. This is due to the coarser division of the starch solids. This photograph was taken six hours after freezing. Compare Fig. 8 the same cream 72 hours later and Fig. 9, gelatin cream at the same age.

gelatin per gallon, while 7 contains a like amount of starch. The division of gelatin in such a solution is much finer than starch. It will be noted that the ice crystals in the gelatin cream are smaller and more regularly distributed. These creams were held under the same conditions for 72 hours, during which time each softened three times and was hardened again by freezing. Figure 8 shows the gelatin cream and figure 9 the starch cream. It will be noted that there is a marked difference in the texture of the two creams, the crystals in the starch cream being very much larger than the gelatin cream. This difference was more marked to the taste and eye than

the photographs show. In the starch cream there were ice formations which could readily be separated from the cream with a spoon.

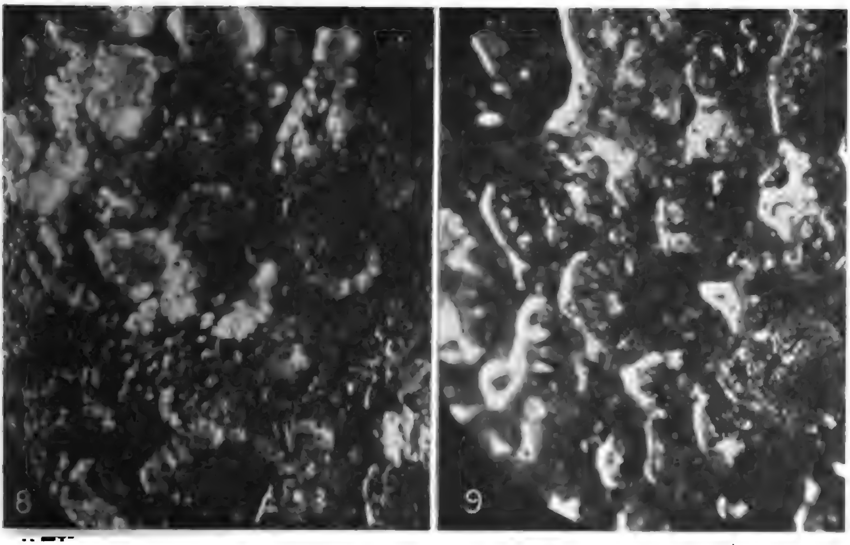


Fig. 8.—Gelatin cream after standing 72 hours; and Fig 9.—Starch cream after standing for the same period. These photographs illustrate the cream shown in Figs. 6 and 7, after having been softened and refrozen three times. Note larger ice crystals in both specimens. The cream shown in Fig. 8 is still in good condition.

Summary.

I.—Smoothness and keeping quality or stability of texture of ice cream are closely associated.

II.—Smoothness depends upon the amount and fineness of division of solids present other than those in true solution, within limits; that is, the smoothness depends upon size and distribution of ice crystals which in turn depend upon the number and nearness together of minute solid particles which interfere with crystallization and reduce the size of the ice crystal.

III.—Colloidal solutions of solids other than fat are best adapted to ice cream making. The finer the division the better.

IV.—The finer the emulsion of the fats the better. The homogenizer has its application in this respect.

V.—The keeping qualities of ice cream depend upon the stability of the "mix." That is, the keeping qualities of ice cream made from a given mixture will depend upon the disposition of the solids in that mixture to separate from the liquid, which in turn depends upon the fineness of division of the solids. The finer the division the better the keeping qualities up to the point at which the solid merges into a true solution.

THE AMOUNT OF ARSENIC IN SOLUTION WHEN LEAD ARSENATE IS ADDED TO DIFFERENT SPRAY SOLUTIONS.[1]

By W. B. Ellett and J. T. Grissom.

There are two classes of parasites that the practical orchardist has to combat, fungus disease and insects. A combination spray which will control both classes of pests is desirable. Lime-sulphur is employed to prevent injury by diseases of apple foliage, and lead arsenate is used to combat the codling moth, which is one of the most serious of the insect pests.

The success with which lime-sulphur has been used, both as a winter spray for San José scale and when combined with lead arsenate as a foliage spray for apple scab and codling moth, has resulted in its wide-spread adoption by fruit growers. Notwithstanding that this combination is now generally used by many orchardists and is considered the most satisfactory of the combination sprays, yet its use is not altogether free from objection. Injury to the foliage and fruit is sometimes severe. This statement not only applies to lime-sulphur used in combination with arsenate of lead, but to combinations of all the sulphur sprays with arsenicals. Such spray applications as contain sodium and potassium sulphides may, under certain conditions, cause all the foliage and fruit to drop. Tests of mixtures containing sodium sulphide have shown them to be much more injurious to foliage and fruit than is ordinary lime-sulphur in combination with lead arsenate. When these sodium mixtures are combined with arsenate of lead, serious damage has often resulted.

Fruit growers are aware of the disadvantages of lime-sulphur used in combination with arsenical sprays, as well as of the injury which follows the use of similar combination sprays. In view of the fact that quite a number of proprietary sprays have been placed on the market and that these are often recommended to be used in combination with lead arsenate and other arsenicals, it is important to determine just what factors are responsible for the foliage injury referred to. There is now much interest manifested in the possibilities of these new spray mixtures. If lead arsenate can be combined with some other of these sulphur sprays, without injuring the foliage, such a combination spray would be welcomed by the orchardists. The problems undertaken in this study was to determine the underlying

[1]This problem was undertaken at the solicitation of Mr. W. J. Schoene, who had become interested in this subject while working with Parrott, at the New York Experiment Station. The office of the State Entomologist furnished the funds to carry on the experiments, and the advice of the Entomologist was helpful in the prosecution of the work.

[2]Clinton and Britton. Conn. Agr. Exp. Sta. Rep't., p. 375, 1911.

cause of the injury referred to, and to discover if possible the form of sulphur that can be used with lead arsenate with least foliage injury.

PREVIOUS WORK.

Bradley[1] studied the amount of soluble arsenic in mixtures of lead arsenate and lime-sulphur solutions. His results indicate that the amount of arsenic in solution was very small and approximate that dissolved by water alone. However, he shows that a slight excess of caustic soda to lime-sulphur increased the amount of soluble arsenic threefold.

Bradley and Tarter[2] made a comparative study of the reactions taking place when either the acid or neutral arsenate of lead was mixed with lime-sulphur under spraying conditions. Their results indicate that eight times as much arsenic is rendered soluble from the acid arsenate as from the neutral. They also studied the effect of alkaline and saline waters on these arsenates and show that more arsenic is dissolved than in pure waters.

Ruth,[3] in discussing his results with lime-sulphur and lead of arsenate mixtures, indicates that the thiosulphates and sulphites are increased and probably explain the increased fungicidal value of the lime-sulphur and lead arsenate mixtures.

ARSENATE OF LEAD COMBINED WITH THE POLYSULPHIDES OF SODIUM, POTASSIUM, CALCIUM AND BARIUM.

Solutions of the different sulphur compounds, i. e., lime-sulphur, barium-sulphur, potassium sulphur and sodium sulphur,, were made, each of which contained three pounds of sulphur per fifty gallons. To these solutions three pounds of lead arsenate paste were added, well mixed, shaken every ten minutes for one hour, and filtered. Analysis was made of the clear solution. Aliquots of the filtrates were analyzed for soluble arsenic. Some of the analyses were made by the modified Gooch and Browning method for soluble arsenic. However, we found that better results could be obtained by the use of the J. and H. S. Patterson Method.[4] After allowing the aliquot to stand 20 minutes with a 10 percent HC1 acid solution, the arsenic was converted to sulphide and polysulphides and filtered on a Gooch filter. No arsenic could be detected in the filtrate, showing that sufficient H_2S was present to precipitate all of the arsenic.

[1] C. E. Bradley. J. Ind. Eng. Chem. V. I. No. 8.
[2] Bradley and Tarter. J. Ind. Eng. Chem. V. II. No. 7.
[3] Ruth, W. E. J. Ind. Eng. Chem. V. 5. No. 10.
[4] Patterson, J. and H. S. Sutton's Volumetric Analysis, p. 161.

Table I.—*The Effect of Sulphur Spray Solutions on the Solubility of Arsenic Pentoxid when Lead Arsenate has been added.*

Form of Sulphur Spray Solution	Percent Arsenic Pentoxid in solution
Lime-sulphur	2.73
Barium solution	1.12
Potassium sulphide	95.00
Sodium sulphide	89.00
Arsenate in water under same conditions	.35

Table I gives the percentage of the As_2O_5 which is in solution in the clear filtrates of the different sulphur spray solutions. More arsenic is in solution when lead arsenate is mixed with the different sulphur sprays than with water. Sodium and potassium sulphides dissolve practically all of the arsenic.

EFFECT OF BARIUM CHLORIDE ON THE SOLUBILITY OF ARSENIC WHEN ARSENATE OF LEAD IS ADDED TO SODIUM SULPHUR SPRAY SOLUTION.

In order to determine the effect of barium chloride on the solubility of the arsenic when lead arsenate is mixed with sodium sulphide, an excess of barium chloride was added to the mixtures according to Table II and the soluble arsenic determined, as below, after one hour and after standing 48 hours. The use of barium chloride has been suggested to prevent the formation of soluble arsenic.

Table II.—*The Effect of Barium Chloride on the Solubility of Arsenic when added to Sodium Sulphur Spray Solutions containing Lead Arsenate.*

One ounce Sulphur, one ounce Paste, and one and one-third ounces Barium Chloride per gallon of water.	Percent of Arsenic Pentoxid in solution after	
	1 hour	48 hours
1.—Mix barium chloride and sodium sulphide thoroughly and add the arsenate	2.51	2.09
2.—Mix barium chloride and arsenate and then add the sodium sulphide	11.75	1.78
3.—Mix arsenate and sodium sulphide and then add the barium chloride	11.75	1.00

The results show that nearly all of the arsenic is removed from solution by the barium chloride, probably as the normal barium arsenate. Barium arsenate is slightly soluble in water and this solubility was increased in two

instances by the presence of sodium salts. In the same manner the solubility of calcium arsenate or lead arsenate is probably increased by the presence of the polysulphides of calcium when the lead arsenate and lime-sulphur sprays are mixed.

A comparison of Tables I and II shows that the soluble arsenic is not as great as when lead arsenate is used with barium-sulphur or lime-sulphur as it is when lead arsenate is used with sodium sulphide with an excess of barium chloride present.

THE EFFECT OF SULPHUR SPRAYS ON THE SOLUBILITY OF ARSENIC OF PARIS GREEN.

The summer strength sulphur solutions were made as before, and, instead of lead arsenate, Paris green was added at the rate of one-half pound to 50 gallons of the solution. The arsenic was estimated by the same method. The amount of arsenic in solution was found to be much greater than when lead arsenate was used. The results are shown in Table III.

TABLE III.—*Soluble Arsenic Oxide, when Paris Green is added to the Sulphur Spray Solutions.*

One-half pound Paris green in sulphur spray solution, diluted to contain three pounds sulphur per fifty gallons.

Spray Solution	Percent Arsenic Pentoxid in solution
Lime-sulphur	42.06
Barium-sulphur	35.07
Potassium-sulphur	74.95
Sodium-sulphur	79.17

THE EFFECT OF VARIOUS SULPHUR SPRAY SOLUTIONS ON THE SOLUBILITY OF THE ARSENIC OXIDE OF BARIUM ARSENATE.

In order to determine the effect of sulphur compounds on barium arsenate, mixtures were made containing one ounce of sulphur per gallon in the form of lime-sulphur, barium-sulphur, potassium sulphide and sodium sulphide. To each of these was added one ounce of barium arsenate per gallon. The mixtures were agitated every ten minutes for one hour, filtered, and the amount of arsenic determined in the clear filtrate. The arsenic oxide given represents the percentage of arsenic oxide of the original barium arsenate which was held in solution when the arsenic was mixed with the sulphides.

	Percent of original Arsenic Pentoxid in solution
Lime-sulphur Barium arsenate	.18
Barium-sulphur Barium arsenate	.18
Potassium-sulphide Barium arsenate	17.39
Sodium sulphide Barium arsenate	6.21
Barium-arsenate alone in water	15.00

Analysis of Barium Arsenate.

Moisture	45.90 percent
Total Barium Oxide (BaO)	26.84 percent
Total Arsenic Oxide (As_2O_5)	17.42 percent
Soluble Arsenic Oxide (As_2O_5)	10.69 percent
Soluble Barium Oxide (BaO)	11.38 percent

Conclusions.

Sodium and potassium sulphides dissolve more arsenic when mixed with lead arsenate than the commercial lime and barium sulphur spray solutions. When arsenate of lead is added to either the summer strength of sodium sulphur or potassium sulphur a large percent of arsenic goes into solution. Barium chloride retards the solubility of the arsenic when added to sodium and potassium sulphides.

When lead arsenate is added to the different sulphur spray solutions the amount of arsenic in solution is increased. This accounts for the burning effect when used together as a spray.

The arsenic in solution is in the form of sulphides, polysulphides, and thioarsenate, and arsenates of the different alkali present and when oxidized, would form arsenates and arsenites.

With calcium and barium the arsenic is less soluble than sodium and potassium. The results of Table III indicate that, if mixtures with arsenic are desired for spraying, lead arsenate is less harmful than Paris green.

Barium arsenate, when used with the different sulphur sprays, indicates that slight burning would take place with lime and barium sulphur and that the amount of arsenic in solution is less than when used with water. With sodium and potassium sulphides this substance would be harmful.

METEOROLOGICAL RECORDS FOR 1913 AND 1914.

H. L. PRICE, *Observer.*

Reading of the Standard Air Thermometer, 1913.

Date	January			February			March			April			May			June		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	35	50	30	29	27	20	42	60	42	43	56	52	40	75	50	60	83	68
2	24	51	42	13	39	35	28	34	27	47	69	57	50	83	56	65	78	65
3	33	25	25	32	45	42	24	52	41	49	76	60	50	86	64	65	81	70
4	28	45	35	29	38	30	32	48	41	59	70	58	56	87	56	64	78	67
5	30	59	39	22	35	28	38	46	37	41	51	43	51	87	50	65	75	60
6	53	58	53	24	28	23	34	30	21	37	49	41	55	82	62	63	80	67
7	50	71	56	17	31	23	15	29	26	34	53	45	57	60	53	67	83	65
8	62	47	29	18	33	30	28	53	43	32	46	44	52	60	53	68	57	53
9	22	37	25	23	40	36	30	64	52	42	52	45	46	75	59	50	58	47
10	17	35	38	25	44	37	43	45	44	43	43	39	51	61	53	48	56	43
11	35	66	52	34	41	42	48	52	36	56	38	53	41	60	46	44	58	50
12	52	35	32	35	29	18	32	54	50	49	54	51	40	67	58	50	72	60
13	24	35	23	7	28	21	46	48	47	52	60	53	48	75	59	58	78	67
14	18	46	32	13	48	32	50	64	57	45	52	45	59	75	65	67	81	65
15	18	50	32	19	46	31	54	65	52	36	52	42	58	72	57	59	84	64
16	34	56	42	27	57	39	38	30	25	47	60	55	61	76	61	67	83	71
17	41	62	65	38	51	42	28	42	30	46	68	47	59	70	56	67	86	69
18	47	55	50	25	54	40	25	53	41	39	76	55	60	73	58	65	80	67
19	26	55	38	27	59	40	33	48	53	53	65	48	59	73	54	65	85	71
20	35	58	54	39	51	48	47	64	60	45	59	42	60	70	63	69	88	73
21	38	39	29	47	52	50	62	64	57	30	58	42	63	69	60	73	87	71
22	32	50	41	50	67	47	36	51	37	37	74	54	62	74	60	69	78	71
23	37	46	45	33	46	36	41	62	45	54	78	55	62	60	53	66	81	65
24	48	55	50	30	35	25	54	64	61	48	81	56	50	60	54	67	81	69
25	44	53	44	21	33	31	63	70	64	46	80	56	56	70	60	65	71	66
26	29	56	42	31	46	43	64	56	56	52	72	50	55	74	62	63	86	70
27	38	35	32	48	57	53	53	32	29	44	53	42	59	64	50	67	78	69
28	20	40	35	45	62	43	25	39	30	56	45	40	56	63	60	71	88	77
29	30	42	31	..	..	..	29	56	45	42	53	52	59	73	63	72	82	73
30	25	57	44	..	..	..	41	52	49	43	68	47	62	80	66	67	85	74
31	44	51	34	..	..	..	48	66	52	..	..	..	66	76	60	..	..	..
Averages	34	49	39	29	40	35	40	51	44	45	60	49	55	72	51	64	78	65

NOTE.—The temperature readings are recorded in degrees Fahrenheit.

Reading of the Standard Air Thermometer, 1913.

Date	July			August			September			October			November			December		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	72	90	76	68	85	70	59	86	66	60	70	65	18	48	36	40	41	40
2	73	87	68	70	86	67	59	82	62	60	62	50	30	58	35	40	49	47
3	69	83	66	65	86	68	63	74	64	51	58	54	24	64	44	45	53	51
4	68	79	69	61	85	68	65	77	68	50	72	49	37	61	46	47	56	44
5	69	85	74	66	79	70	62	81	67	43	70	50	26	59	45	41	58	45
6	73	81	71	64	83	70	65	84	68	41	72	57	23	64	47	32	38	45
7	61	72	59	65	76	71	65	85	69	50	68	61	27	65	46	47	52	30
8	55	77	62	63	84	71	63	69	64	61	73	66	41	50	45	14	27	22
9	63	82	71	64	90	67	64	71	52	64	67	64	30	30	26	18	34	28
10	69	84	67	68	86	72	44	68	48	63	70	60	26	27	22	17	43	37
11	66	78	69	71	82	71	39	76	58	63	76	59	20	25	25	32	39	30
12	70	76	68	65	68	62	54	79	67	46	68	47	23	51	36	25	55	35
13	66	83	72	62	77	71	60	76	52	46	60	47	36	65	37	25	54	29
14	67	82	69	67	79	66	51	61	56	32	71	46	42	62	54	26	52	45
15	68	78	70	65	76	69	52	56	55	52	71	62	47	46	46	28	52	33
16	65	84	72	60	78	67	54	59	57	56	74	54	48	55	51	23	54	44
17	67	84	75	60	84	68	56	66	62	47	72	59	36	53	40	31	54	40
18	75	89	79	63	88	67	61	66	64	56	55	59	33	63	50	43	48	32
19	71	90	65	67	82	70	61	72	62	50	47	47	38	71	49	17	44	27
20	64	80	65	62	65	65	63	79	68	43	37	38	42	66	49	24	52	35
21	60	79	63	60	71	64	56	53	45	33	38	30	35	70	44	29	52	37
22	59	73	67	63	67	67	38	53	40	24	52	39	34	71	45	26	49	37
23	65	82	70	66	78	68	36	67	46	30	56	50	50	65	54	36	42	40
24	69	82	68	63	77	64	39	70	48	51	57	57	39	48	42	29	44	40
25	65	78	67	55	75	63	40	75	53	56	61	50	26	54	31	35	35	34
26	63	80	67	58	82	66	44	77	59	45	59	43	37	60	42	33	31	28
27	66	85	70	63	84	66	59	68	61	31	67	58	43	49	47	18	34	23
28	68	80	70	61	87	70	57	69	59	47	68	43	43	48	44	26	37	33
29	69	90	74	70	80	64	57	71	62	29	58	44	42	56	48	33	38	35
30	69	92	71	58	79	60	62	78	68	38	35	36	43	41	40	31	44	26
31	70	93	75	59	83	66	..	..	..	36	38	35	..	..	..	26	31	31
Averages	67	83	69	64	80	67	55	72	59	47	61	51	35	55	42	30	45	36

Reading of the Standard Air Thermometer, 1914.

Date	January			February			March			April			May			June		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	32	32	31	35	45	35	35	20	13	40	48	53	37	63	52	65	85	69
2	30	32	25	21	47	38	8	23	23	50	50	45	41	68	49	66	78	66
3	29	32	29	25	39	47	21	38	35	41	52	41	45	74	63	54	79	65
4	29	32	32	47	55	42	35	45	34	28	53	45	53	72	61	69	81	73
5	30	32	25	41	53	46	31	33	31	37	48	39	60	68	64	65	69	61
6	29	32	29	32	33	33	31	35	31	28	57	47	62	69	57	60	67	60
7	29	32	32	45	39	22	24	37	24	37	64	58	57	68	59	69	84	71
8	27	43	38	14	28	22	28	29	26	53	45	34	54	62	45	69	89	75
9	40	40	39	18	34	29	23	23	28	26	41	30	44	62	49	70	91	68
10	33	33	29	25	41	29	27	45	38	21	48	39	47	75	63	69	91	74
11	28	27	26	30	30	30	36	38	33	31	62	55	60	82	65	72	93	94
12	27	29	17	21	28	21	21	38	29	46	59	54	64	87	75	73	93	67
13	11	24	24	10	13	15	22	37	30	32	65	51	61	75	59	69	86	78
14	7	38	27	18	26	20	22	52	39	41	43	42	52	64	45	65	82	68
15	23	42	37	14	23	20	40	63	54	43	50	48	44	64	50	68	84	70
16	29	40	48	25	17	14	35	70	55	49	55	53	43	64	49	66	78	57
17	34	36	30	9	39	40	39	56	42	44	67	65	45	70	56	62	75	62
18	23	*	32	38	45	40	34	32	27	45	81	66	50	71	51	59	60	55
19	32	41	40	38	50	42	20	34	33	59	69	61	49	74	55	58	80	69
20	41	59	49	32	28	36	26	30	14	47	51	40	48	79	55	64	82	75
21	33	33	30	15	34	20	3	28	26	36	50	49	49	81	62	67	91	77
22	25	35	30	16	50	38	23	35	25	39	79	63	55	83	67	75	93	82
23	21	56	41	36	24	20	20	44	35	53	72	60	67	83	62	76	92	81
24	39	43	41	14	27	17	28	58	45	49	66	54	65	83	63	73	92	78
25	31	38	35	7	29	24	42	61	50	50	76	68	62	89	63	72	96	72
26	27	46	30	18	43	25	50	63	55	60	73	63	58	81	65	69	93	76
27	32	47	35	20	43	24	47	64	58	57	81	64	60	88	65	71	94	72
28	32	65	48	26	43	37	54	70	63	59	80	65	63	84	69	71	95	80
29	41	67	55	..	..	..	51	49	44	59	73	63	64	89	69	69	84	70
30	50	63	60	..	..	..	43	62	63	60	65	47	62	87	65	63	83	70
31	61	44	33	..	..	..	52	47	44	..	..	..	65	83	65	..	..	..
Averages	31	39	35	25	36	29	31	44	37	44	61	52	54	78	59	67	84	70

*No record.

Reading of the Standard Air Thermometer, 1914.

Date	July			August			September			October			November			December		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	67	82	69	56	80	63	64	84	68	42	73	49	31	66	46	53	56	55
2	65	77	65	60	84	65	63	88	70	43	68	56	46	66	45	52	55	53
3	63	82	72	63	80	64	67	78	62	52	60	57	38	70	51	43	57	53
4	67	71	67	66	71	65	60	75	61	58	60	59	39	71	61	48	42	40
5	64	74	66	58	74	63	49	75	59	59	68	59	47	57	45	37	38	36
6	59	70	64	60	82	67	55	82	69	59	76	60	44	57	38	33	35	34
7	68	78	65	61	86	65	63	81	68	55	76	61	33	70	47	34	41	44
8	62	82	71	64	86	72	61	70	63	52	69	60	42	67	45	40	45	40
9	66	86	63	69	82	71	54	62	56	56	79	62	33	41	28	38	41	38
10	62	83	72	68	80	70	43	65	52	58	80	66	19	47	33	33	32	29
11	64	88	74	66	82	70	51	52	53	59	74	56	40	55	41	27	30	28
12	68	92	71	68	82	68	52	55	52	46	73	63	26	63	38	25	32	25
13	67	90	70	61	79	65	52	61	54	50	62	57	30	60	41	28	28	33
14	66	79	73	61	77	65	50	63	55	56	55	53	32	47	46	28	22	10
15	66	76	70	65	80	64	49	67	53	54	58	60	50	55	53	1	17	11
16	67	77	70	61	82	67	50	68	61	57	66	53	45	44	30	1	29	1
17	70	72	70	59	81	68	58	63	63	38	62	51	20	28	22	11	31	14
18	71	83	69	59	89	70	64	74	66	45	55	42	13	35	24	10	32	29
19	62	76	63	63	91	72	63	77	66	35	64	46	25	44	30	26	30	35
20	56	80	67	69	80	69	56	81	68	39	67	51	17	21	15	33	34	32
21	62	84	68	64	79	68	56	85	65	46	73	50	15	34	24	32	44	32
22	64	87	70	64	84	74	56	87	65	40	72	59	21	45	26	25	30	27
23	63	89	72	69	88	69	57	85	63	56	63	55	25	38	22	25	36	27
24	69	88	80	68	81	73	55	60	55	52	60	57	12	43	28	30	30	34
25	71	90	96	67	85	70	48	60	53	47	64	47	29	53	36	32	30	24
26	67	66	68	65	74	65	45	64	51	46	59	48	39	58	41	7	17	7
27	66	87	72	63	69	66	36	68	52	32	38	31	30	57	44	4	22	5
28	69	83	72	66	82	69	42	72	51	23	51	39	44	46	43	−2	34	31
29	62	76	63	65	80	70	38	71	52	34	52	47	40	43	47	31	39	32
30	60	60	58	64	77	62	47	75	52	41	54	45	49	54	50	37	33	32
31	50	73	62	57	81	65	..	..	..	32	62	35	..	..	..	25	31	23
Averages	64	80	69	63	81	67	53	72	59	47	64	51	32	51	38	27	35	30

Table showing meteorological data, January 1, 1913, to December 31, 1913.

1913	Mean Temp. for Mo.	Mean Maximum Temp. for Mo.	Mean Minimum Temp. for Mo.	Average daily range	Highest Temp.	Lowest Temp.	Mo'thly range	Precipitation in inches	Snow in inches	Prevailing winds	Number of clear days	Number of partly cloudy days	Number of cloudy days
January	42	53	31	23	72	16	56	1.59	2.	W	12	10	9
February	36	45	27	18	67	6	61	2.46	3.5	W	15	5	8
March	47	56	38	17	71	14	57	3.97	....	W	12	7	12
April	51	63	39	25	83	24	59	2.81	....	W	16	7	7
May	60	74	46	28	87	27	60	4.97	....	W	20	6	5
June	68	81	55	26	90	38	52	4.58	....	W	14	12	4
July	73	85	61	23	94	47	47	5.38	....	W	23	7	1
August	71	82	59	23	93	48	45	3.31	....	W	18	7	6
September	62	74	50	24	87	32	55	2.99	....	E	15	6	9
October	53	64	41	23	80	20	60	3.05	T	W	7	10	14
November	44	58	30	27	76	18	58	2.37	1.0	W	13	6	11
December	38	48	27	21	66	11	55	2.44	0.5	W	12	6	13

Table showing meteorological data, January 1, 1914, to December 31, 1914.

1914	Mean Temp. for Mo.	Mean Maximum Temp. for Mo.	Mean Minimum Temp. for Mo.	Average daily range	Highest Temp.	Lowest Temp.	Mo'thly range	Precipitation in inches	Snow in inches	Prevailing winds	Number of clear days	Number of partly cloudy days	Number of cloudy days
January	35	44	26	18	69	6	63	3.11	16.5	W	3	10	18
February	31	41	21	19	62	5	57	4.09	13.5	E	12	4	12
March	37	48	27	21	71	1	70	3.95	11.5	W	8	7	16
April	52	65	39	25	84	19	65	2.38	....	W	8	11	11
May	61	77	45	32	91	30	61	0.76	....	W	16	10	5
June	73	87	59	28	99	45	54	0.63	....	NW	7	22	4
July	71	83	59	24	94	44	50	9.40	....	NW	4	23	4
August	71	83	58	25	93	49	44	4.51	....	NW	8	15	8
September	62	74	49	24	89	34	55	2.32	....	E	14	10	6
October	56	66	45	21	81	23	58	3.63	....	W	17	7	7
November	41	54	28	25	72	9	63	1.99	1.5	W	20	3	7
December	31	38	23	15	58	-15	73	8.06	14.0	E	6	2	23

ANNUAL REPORT

OF THE

VIRGINIA POLYTECHNIC INSTITUTE

Agricultural Experiment Station

1915, 1916

CONTENTS

The more popular and immediately applicable results of the work of this Experiment Station are presented in Bulletins and Circulars, which are for general distribution. This Report contains, aside from a brief statement of the work in progress, the following Technical Bulletins and Special Articles:

TECHNICAL BULLETINS

SPECIAL ARTICLES

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

1915, 1916

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

LYNCHBURG, VA.
BROWN-MORRISON CO., INC., PRINTERS
1917

CONTENTS

LETTER OF TRANSMITTAL

To His Excellency, Governor Henry C. Stuart:

SIR: In accordance with the Federal laws, approved March 2, 1887, and March 20, 1906, I transmit for your consideration the report of the Virginia Agricultural Experiment Station for the years 1914-15 and 1915-16.

Respectfully submitted,

A. W. DRINKARD, JR., *Director.*

June 1, 1917.

ORGANIZATION

OF THE

VIRGINIA AGRICULTURAL EXPERIMENT STATION

STATION STAFF

J. D. EGGLESTON, A. M.	President
A. W. DRINKARD, JR., Ph. D.	Director
H. L. PRICE, M. S.	Horticulturist
W. B. ELLETT, Ph. D.	Chemist
W. J. SCHOENE, M. S.	Entomologist
T. B. HUTCHESON, M. S.	Agronomist
F. D. FROMME, Ph. D.	Plant Pathologist and Bacteriologist
H. H. HILL, M. S.	Associate Chemist
R. E. HUNT, M. S.	Associate Animal Husbandman
C. W. HOLDAWAY, M. S.	Associate Dairy Husbandman
E. R. HODGSON, M. S.	Associate Agronomist
T. J. MURRAY, M. S.	Associate Bacteriologist
T. K. WOLFE, M. S.	Assistant Agronomist
H. E. THOMAS, M. S.	Assistant Plant Pathologist
A. A. INGHAM, M. S.	Assistant Horticulturist
C. I. WADE	Treasurer
J. B. FOGLEMAN	Executive Clerk

COUNTY EXPERIMENT STATIONS

E. R. HODGSON, M. S.	Supervisor County Experiment Stations
W. W. GREEN, (Bowling Green)	Supervisor Tobacco Investigations, and Superintendent Bowling Green and Louisa Station
B. G. ANDERSON, B. S. (Appomattox)	Superintendent Appomattox Station
R. P. COCKE, (Williamsburg)	Superintendent Williamsburg and Lightfoot Stations
*J. M. TRIMBLE, M. S. (Staunton)	Superintendent Staunton Station
J. C. HART, B. S. (Chatham)	Superintendent Chatham Station
*A. N. HODGSON, M. S. (Martinsville)	Superintendent Martinsville Station
*A. P. MOORE, B. S. (Charlotte C. H.)	Superintendent Charlotte Station
E. T. BATTEN, B. S. (Holland)	Superintendent Holland Station

*In coöperation with the State Board of Agriculture.

Bulletins and reports are mailed free to all residents of the State who apply for them.

Virginia Agricultural Experiment Station

REPORT OF THE DIRECTOR

President J. D. Eggleston,
Virginia Polytechnic Institute.

SIR: I submit herewith a report of the work of the Virginia Agricultural Experiment Station for the fiscal years 1914-1915 and 1915-1916. The experimental and research work was actively and successfully continued during this period, yielding results of great value to agriculture.

Publications

During the two-year period covered by this report, four bulletins were issued.

Bulletin No. 209—The Frog-Eye Leaf Spot of Apples, by C. H. Crabill.
Bulletin No. 210—A Stone-Fruit Spray Made from Hydrated Lime and Sulphur, by G. C. Starcher.
Bulletin No. 211—Effects of Binders upon the Melting and Hardness of Ice Cream, by C. W. Holdaway and R. R. Reynolds.
Technical Bulletin No. 10—Some Effects of Temperature upon the Growth and Activity of Bacteria in Milk, by H. S. Reed and R. R. Reynolds.

In addition to the regular publications of the Station, members of the staff contributed papers to various other publications which are here cited.

Crabill, C. H.—Dimorphism in *Coniothyrium pirinum*. American Journal of Botany **2**: 449-467. 1915.
Crabill, C. H.—Note on Apple Root-Rot in Virginia. Phytopathology **6**: 159-161. 1916.
Crabill, C. H.—Note on White Spot of Alfalfa. Phytopathology **6**: 91-93. 1916.
Crabill, C. H., and Thomas, H. E.—Stippen and Spray Injury. Phytopathology **6**: 51-54. 1916.
Fromme, F. D.—Violet Root-Rot of Alfalfa in Virginia. Phytopathology **6**: 90. 1916.
Holdaway, C. W.—Statistical Weighting for Age of Advanced Registry Cows. American Naturalist **50**: 676-687. 1916.
Hunt, R. E., and others—Directory of Virginia Breeders of Purebred Livestock. Virginia Polytechnic Institute Extension Bulletin No. 5. 1916.

Murray, T. J.—The Oxygen Requirements of Biological Soil Processes. Journal Bacteriology **1**: 597-614. 1916.

Reed, H. S., and Grissom, J. T.—The Development of Alkalinity in Glomorella Cultures. Journal Biological Chemistry **21**: 159-163. 1915.

Reed, H. S., and Williams, Bruce—The Effect of Some Organic Soil Constituents upon Nitrogen Fixation by Azotobacter. Centralbl. f. Bakt. 2 Abt. **43**: 166. 1915.

Smulyan, M. T.—Observations on the Life Histories and Habits of the Species of Aphides most common on the cultivated Apple (Malus Malus) in Virginia (Blacksburg), during the season of 1915. Tenth Report of the State Entomologist and Plant Pathologist of Virginia, pp. 64-75. 1916.

Starcher, G. C.—Peach Growing in Virginia. Virginia Polytechnic Institute Extension Bulletin No. 1. 1915.

Williams, Bruce—Some Factors Influencing Nitrogen Fixation and Nitrification. Botanical Gazette **62**: 311-317. 1916.

Wolfe, T. K.—Further Evidence of the Immediate Effect of Crossing Varieties of Corn on the Size of Seed Produced. Journal American Society of Agronomy **7**: 265-272. 1915.

Wolfe, T. K.—Fasciation in Maize Kernels. American Naturalist **50**: 306-309. 1916.

Other technical investigations completed during this period are published as a part of this report.

The Staff

The staff of scientific workers consists of twenty-two men; eleven of these men divide their time between the Station and some other branch of institutional work, and eleven devote all their time to the Station.

Several changes occurred during the period covered by this report. The late Professor W. K. Brainerd, who was appointed Dairy Husbandman in 1908, resigned in 1914, after six years of service, to accept a position with the U. S. Department of Agriculture. The experimental work in Dairy Husbandry was assigned to Professors Hunt and Holdaway. Dr. H. S. Reed, Plant Pathologist and Bacteriologist since 1908, resigned July 1, 1915, to accept the position Plant Physiologist at the California Citrus Experiment Station, and Dr. F. D. Fromme was appointed in his stead. Mr. W. G. Harris, Assistant Chemist, resigned July 1, 1915, and was succeeded by Mr. J. T. Grissom. Mr. D. D. Digges, Superintendent of the Charlotte County Experiment Station, resigned September 1, 1915, and Mr. R. H. Cook was appointed in his place. Mr. Bruce Williams, Assistant Bacteriologist, resigned September 1, 1915, and Mr. T. J. Murray was appointed Associate Bacteriologist in his stead. Mr. C. H. Crabill, Assistant Plant

Pathologist, resigned September 1, 1915, and Mr. K. E. Quantz was appointed Assistant in Plant Pathology, September 1, 1915.

Mr. W. J. Schœne, State Entomologist, served as Acting Director during the two years covered by this report, and A. W. Drinkard, Jr., was appointed Director at the end of this period.

Finances

The finances of the Station are explained in detail in the Treasurer's report. The Station received the usual appropriations from the Federal Government. The General Assembly appropriated $8,500.00 annually for experiments with tobacco and crops grown in rotation with tobacco; and $7,500.00 annually for County Experiment Stations.

This Experiment Station received an annual appropriation of $7,500.00 from the State Board of Agriculture for the support of the County Experiment Stations at Staunton, Martinsville and Charlotte Court House. The annual income for the period covered by this report is shown approximately by the following statement:

Federal Funds	Adams Fund	$15,000.00
	Hatch Fund	15,000.00
State Funds	Appropriations from the General Assembly	16,000.00
	Appropriations from the State Board of Agriculture	7,500.00
Sale of produce, etc.		2,000.00
Total annual income		$55,000.00

Lines of Work for Which There is Pressing Need of Investigation

There are several lines of work along which there is large demand for experimental information. Since the present income of the Station is restricted by law to specific lines of work, it is not possible for the Station to undertake additional investigations with its present income.

Animal Husbandry and Grazing Experiments.—The Station has given some attention to this line of work, but its resources have never been sufficient to carry out the larger investigations needed. Farmers desire information regarding feeds, feeding and grazing, and the importance of this branch of farming in the State seems to justify State support for this work.

Poultry Husbandry.—Nearly every farmer in the State raises some poultry, and there are a number of farms on which poultry raising is a commercial undertaking. There is wide demand for information along this line. The Station has never undertaken experiments with poultry, but it is clear that this branch of farming could be greatly increased by supplying the farmers needed information from carefully conducted experiments.

Soil and Crop Survey.—The problem of finding out the adaptation of particular crops to soils is always and everywhere very important. The

Station has numerous requests for information about the soils of the State. In many cases this information is not available, and it is important to have analyses of the leading soil types in the State and to find out what crops succeed best on these soil types, what fertilizer treatments are required, and what systems of cultivation are necessary to secure the best yields from different soil types. A limited amount of information is being secured along this line at all the County Stations, but there is need for State support of general surveys along these lines.

Experimental Work

Since the last report was issued the following investigations have been completed or discontinued:

Analyses and preparation of nicotine sprays
Forage crops for hogs
Cause and control of peach yellows

List of Projects and Experiments Conducted by the Virginia Agricultural Experiment Station

HORTICULTURAL DEPARTMENT

1. *Effect of soil environment on fruit-bud formation
2. *Breeding late-blooming apples
3. Studies of the laws of inheritance in garden vegetables
4. Commercial value of Dwarf apples
5. The control of fire blight
6. Varietal studies of tree fruits
7. Experiment orchards at several points in the State, for study of orchard spraying, fertilizing and soil management

CHEMICAL DEPARTMENT

1. *Fixation of phosphoric acid in soils
2. The fertility of Virginia soils
3. *Protein and energy requirements for milk production (in coöperation with the Dairy Husbandry Department)
4. *Effect of green manuring on the soil

AGRONOMY DEPARTMENT

1. *Growth and maturity of corn
2. Pasture management
3. Cereal investigations
4. Forage crop investigations, including experiments with soy beans and other field crops
5. Alfalfa experiments
6. Weed eradication
7. Field experiments with farm crops—crop rotation and fertilizer experiments at Blacksburg and the nine (9) County Experiment Stations

ANIMAL AND DAIRY HUSBANDRY DEPARTMENTS

1. *Protein and energy requirements for milk production (in coöperation with the Chemical Department)
2. Wintering steers

PLANT PATHOLOGY AND BACTERIOLOGY DEPARTMENTS

1. *Relation of parasitic fungi and bacteria to their host plant
2. Principles of infection by uredineous fungi
3. Plant disease survey of Virginia
4. Field experiments on plant diseases (apple foliage diseases, alfalfa diseases, tomato blight, cedar rust)
5. *Study of the organisms affecting the nitrogen compounds of the soil
6. Legume bacteria and inoculation
7. *Black root-rot of the apple

*Adams Fund.

An account of the work of the different departments of the Station is given in the following pages.

Respectfully submitted,

A. W. DRINKARD, JR., *Director.*

REPORT OF THE TREASURER

Federal Funds

From July 1, 1914, to July 1, 1915.

RECEIPTS	HATCH FUND	ADAMS FUND	SUPPLEMENTAL FUND
Treasurer United States	$ 14,997.32	$ 14,999.70	———
Balance from appropriations 1913-14	2.68	.30	$ 425.11
Sundries	———	———	2,456.72
Interest on bank balances	———	———	165.62
Totals	$ 15,000.00	$ 15,000.00	$ 3,047.45
DISBURSEMENTS			
Salaries	$ 7,823.29	$ 9,681.64	———
Labor	2,424.00	1,869.87	$ 21.40
Publications	1,265.99	———	———
Postage and stationery	457.02	6.30	4.00
Freight and express	180.87	83.67	6.04
Heat, light, water and power	205.00	93.63	———
Chemicals and laboratory supplies	162.29	743.74	9.55
Seeds, plants and sundry supplies	604.43	357.07	63.05
Fertilizers	298.70	151.69	3.55
Feeding stuffs	368.71	890.83	———
Library	254.80	———	4.70
Tools, machinery and appliances	401.84	225.79	———
Furniture and fixtures	30.53	35.00	156.33
Scientific apparatus and specimens	163.74	389.25	———
Live stock	———	———	9.50
Traveling expenses	174.02	247.22	———
Contingent expenses	20.00	———	37.00
Buildings and land	164.77	224.05	608.28
Balances	———	.25	2,124.05
Totals	$ 15,000.00	$ 15,000.00	$ 3,047.45
Balances, July 1, 1915	———	$ .25	$ 2,124.05

From July 1, 1915, to July 1, 1916.

RECEIPTS	HATCH FUND	ADAMS FUND	SUPPLEMENTAL FUND
Treasurer United States	$ 15,000.00	$ 14,999.75	———
Balance from appropriations 1914-15	———	.25	$ 2,124.05
Sundries	———	———	2,210.55
Interest on bank balances	———	———	237.95
Totals	$ 15,000.00	$ 15,000.00	$ 4,572.55

DISBURSEMENTS			
Salaries	$ 7,753.22	$ 10,542.18	
Labor	2,848.03	1,774.88	$ 429.23
Publications	491.73		
Postage and stationery	477.90	.80	71.32
Freight and express	170.95	77.75	3.61
Heat, light, water and power	291.75	49.22	7.49
Chemicals and laboratory supplies	140.24	192.41	11.58
Seeds, plants and sundry supplies	644.71	378.43	47.23
Fertilizers	386.77	205.25	2.50
Feeding stuffs	371.89	729.80	102.66
Library	241.64		5.00
Tools, implements and machinery	211.91	162.64	111.18
Furniture and fixtures	23.57	13.48	3.43
Scientific apparatus and specimens	5.03	96.81	75.00
Live stock	120.00		270.00
Traveling expenses	283.30	250.44	5.00
Contingent expenses	40.00		
Buildings and land	497.36	525.91	84.09
Balance			3,343.23
Totals	$ 15,000.00	$ 15,000.00	$ 4,572.55

State Funds

From July 1, 1914, to July 1, 1915.

RECEIPTS	STATE FUND	STATE BOARD OF AGRICULTURE FUND
Balances, July 1, 1914	$ 23.83	$ 1,073.53
State appropriation for tobacco experiments	8,500.00	
State appropriation for county experiments	7,500.00	
Sundry stations, etc.	750.64	593.62
Bank interest on balances	31.83	37.17
Commissioner of Agriculture Koiner		7,500.00
Total receipts	$ 16,806.30	$ 9,204.32

DISBURSEMENTS		
Freight and express	$ 32.52	$ 57.47
Postage and stationery	100.19	57.44
Printing	731.25	180.10
Salaries	8,552.15	3,328.96
Tools, machinery, etc.	112.50	978.04
Furniture and fixtures	.25	
Live stock	140.00	212.50
Travel expenses	695.17	350.37
Repairs and buildings	623.11	298.88
Contingent	503.00	109.00
Heat, light and water	.30	3.75
Seeds, plants and sundry supplies	464.72	734.36
Fertilizers	980.22	417.51
Chemical supplies	67.05	6.95
Feed stuffs	120.32	191.02
Labor	3,173.59	1,633.32
Balances	509.96	644.65
Total receipts	$ 16,806.30	$ 9,204.32
Balances, July 1, 1915	$ 509.96	$ 644.65

From July 1, 1915, to July 1, 1916.

RECEIPTS	STATE FUND	STATE BOARD OF AGRICULTURE FUND
Balances, July 1, 1915	$ 509.96	$ 644.65
Appropriation for tobacco and counties	15,999.99	—
Commissioner of Agriculture Koiner	—	7,125.00
Sundry stations, etc.	622.36	1,228.74
Bank, interest and balances	43.65	31.25
Totals	$ 17,175.96	$ 9,029.64

DISBURSEMENTS		
Freight and express	$ 66.75	$ 24.86
Postage and stationery	92.83	58.84
Library	2.75	—
Salaries	8,783.33	3,333.30
Tools, implements and machinery	109.88	120.95
Live stock	35.00	190.00
Traveling expenses	829.39	204.21
Buildings and lands	379.03	156.71
Contingent	52.05	4.00
Seeds, plants and sundries	998.40	458.28
Fertilizers	650.87	281.60
Chemical supplies	—	12.58
Heat, light and water	—	5.00
Feed stuffs	402.97	77.46
Scientific apparatus	18.75	—
Labor	3,642.54	1,566.02
Balances	1,111.42	2,535.83
Totals	$ 17,175.96	$ 9,029.64
Balances, July 1, 1916	$ 1,111.42	$ 2,535.83

CHAS. I. WADE, *Treasurer.*

Department Reports

REPORT OF THE HORTICULTURIST

Dr. A. W. Drinkard, Jr., Director.

SIR: I have the honor to submit the following report of the work of the Horticultural Department for the years 1914-15 and 1915-16.

The Adams fund work outlined in previous reports has been continued without serious interruption. Additional cross-bred seed and plants have been secured in the breeding work for late blooming varieties. A considerable number of these hybrid seedlings have been engrafted on dwarf stocks with the purpose of hastening their fruiting. Some of these grafts are now nearly old enough to produce fruit. Progress has been made in the study of the effect of soil environment on the production of fruit buds. Good crops of peaches have been harvested from trees in these experiments, both at Blacksburg and at Crozet, and valuable data have been secured for the peach on the effect of cultural treatments and various forms of fertilization on crop production. Some time must yet elapse before similar harvest records can be secured for the apple trees of this experiment, but careful and detailed notes have been made each season since the experiment was installed of the effect of the various soil treatments on the growth of the apple trees.

The hybridization work with phlox has been continued. Interesting notes were secured during the year of 1915-16 for the inheritance of various color factors of this ornamental plant. We hope to secure additional light on the subject this year.

The State fund projects in orchard cultivation and fertilization, located at Winchester and Cloverdale, are progressing favorably, and promise to yield important results. The spraying work at Crozet has been completed. and the cultivation and fertilization work carried on at this point under State funds has been discontinued. The work at Fishersville has also been abandoned. Additional observations have been made of the adaptation of varieties for the apple and other tree fruits.

Respectfully submitted,

H. L. PRICE, *Horticulturist.*

REPORT OF THE CHEMIST

Dr. A. W. Drinkard, Jr., Director.

SIR: I have the honor to submit the following report for the Department of Chemistry. The Adams fund projects are as follows:

1. *Fixation of phosphoric acid* by the various soil compounds, and a study of their availability as measured by plant growth and by Fifth Normal Nitric Acid. Ten years' results of this work are recorded in this report.

2. *Green manure project.* The principal work in green manuring under investigation by this department consists of two groups of field experiments. The first group takes into account the effect of green manuring crops upon the biological activities of the soil. Results are being obtained on nitrate accumulation, nitrogen fixation, bacterial counts, ammonification of organic nitrogenous substances, and acid conditions brought about by the turning under of green crops. In addition to the biological investigations chemical work is being done on humus accumulations, carbon increase, and inorganic plant food liberation from such treatments. Two years' results have been obtained and the work is progressing very favorably.

The second group of field experiments takes into account the effect of turning under green manuring crops at different stages of growth and their effect on the soil and succeeding crops. In this work both the plant and the soil are studied. Interesting data in regard to plant composition and soil changes under such treatment are being collected. This work has been in progress for one year and promises to give interesting results.

3. *Feeding experiments with dairy cows to determine the protein and energy requirements for milk production.* This work is being conducted in coöperation with the Department of Dairy Husbandry. This work is outlined as follows:

FEEDING EXPERIMENT *A.*—The determination of the protein and energy requirements for milk production. A preliminary feeding period of ten days was begun April 20, 1916, with six cows, for the purpose of determining their basal feeding requirements. These requirements were determined and the feeding period of one hundred and fifty days was started. The feeding trial consisted of twelve ten-day feeding periods and three ten-day digestion trials, in which the rations were interchanged and readjusted as outlined in the project. After this a maintenance trial for ninety days, with two ten-day digestion trials included, was conducted with three of the cows for the purpose of determining their actual maintenance require-

ments. Heretofore Armby's standards have been usd for this purpose. These data will be published in the near future.

Feeding Experiment *B.*—Physiological effects of wide and narrow rations on cows and on their progeny. The experiment has been followed as outlined, and in addition it was found necessary to secure more complete data in regard to the growth and metabolism of the animals. A digestion trial was made with one cow of each group. The system of measurements was made more complete by increasing the number of body measurements of the individuals and measuring more frequently. The results of the digestion trial of this experiment are given in this report.

The Department of Chemistry is coöperating with the Department of Agronomy on silage investigations and grass clipping experiments. Two years' results will soon be available. In addition to this work the department has conducted some work on a study of the availability of phosphorus from different slag phosphates in coöperation with the Association of Official Agricultural Chemists. An article on this work will be found in this report.

Respectfully submitted,
W. B. Ellett, *Chemist.*

REPORT OF THE PLANT PATHOLOGIST AND BACTERIOLOGIST

Dr. A. W. Drinkard, Jr., Director.

Sir: I am presenting herewith a report on the work of the department of Plant Pathology and Bacteriology for the years 1914-15 and 1915-16.

Completed work.—The studies on the fungi associated with the Frog Eye leaf spot of the apple have been completed and published together with practical control measures for this disease.

The work on Peach Yellows in coöperation with the State Entomologist has been discontinued.

The Oxygen requirements of some of the biological soil processes have been determined and the results published. It was found that ammonification, denitrification and nitrogen fixation proceed in the presence or absence of oxygen while nitrification could not take place in the absence of free oxygen.

A study of the bacterial flora of fresh and decomposing manure has been completed and is submitted herewith for publication.

Work in progress.—The Plant Disease Survey in coöperation with the U. S. Department of Agriculture, has been continued and much valuable

information has been accumulated through correspondence and occasional field trips.

Field experiments for the control of plant diseases have consisted of dusting and spraying for tomato diseases, and the results of the first season's work have been published. The value of the dusting method for the control of cedar rust and diseases of the peach has been under investigation and the results have been prepared for publication. No measure of control was secured for cedar rust, but the results from the peach work were very promising.

Studies on the relative susceptibility of tomato varieties and hybrids to disease are being continued in coöperation with the Department of Horticulture. Data obtained from field trials over several years indicate considerable variation in susceptibility to leaf-spot and it seems probable that resistant varieties of considerable commercial value may be found.

The work on the relation between parasitic fungi and their hosts is being continued chiefly along the lines of studies on the factors which influence inoculation, infection and immunity, the chief objective being the determination of the fundamental basis of immunity to disease in plants.

A study of the nitrogen compounds of soils as affected by bacterial activities is being continued under the Adams fund. Several papers dealing with various phases of the problem have been published or prepared for publication. The effects of different plant tissues on nitrogen fixation are being studied among other things.

Work recently initiated.—The investigations on the black-root-rot disease of the apple have been made a major problem of the department and have been recently taken up as an Adams project. A preliminary report of the fungi found associated with the disease and tests of their pathogenecity has been prepared for publication.

Respectfully submitted,

F. D. FROMME, *Plant Pathologist and Bacteriologist.*

REPORT OF THE AGRONOMIST

Dr. A. W. Drinkard, Jr., Director.

SIR: I have the honor to submit the following report for the Department of Agronomy.

The cereal investigations have been continued as previously outlined and reported. Several superior strains of wheat and oats have been

segregated and are now ready for distribution in small quantities to farmers. A selection of seed corn introduced from Wisconsin seems particularly adapted to the high elevations of this state. This is being distributed to farmers for trial. The experiment on methods of corn cultivation has been concluded and published in bulletin 214. The Adams fund work on corn is being continued and a progress report of some of the results obtained is being presented with this report.

A new experiment under the cereal investigation project to determine the proper spacing of the drill row for winter seeded wheat was begun in the fall of 1916.

Under soil management the rotation and fertilizer experiments have been continued. To these have been added an experiment to determine the relative value of the various commercial grades of lime sold in the state, and an experiment to test the relative availability of ground limestone of different degrees of fineness.

An Adams fund experiment in coöperation with the Department of Chemistry to determine the best method of handling green manure crops, was started in the fall of 1915.

The annual forage crop experiments are being continued except for the work with Sudan grass. This was concluded and reported in bulletin 212.

The alfalfa experiments are being continued as outlined, and to them have been added some comparative experiments with sweet clover.

The potato studies have given considerable data which will be reported in bulletin form in the near future.

The pasture management work in coöperation with the United States Department of Forage Investigations, has been continued. Two new phases of this work are: (1) a clipping experiment to determine the relative amount of grass obtained from the most common pasture grasses and the effect of fertilizers on pastures, and (2) an experiment to determine the effect of chemical sprays, cultivation, fertilization and reseeding on certain serious pasture weeds.

Respectfully submitted,

T. B. HUTCHESON, *Agronomist.*

REPORT OF THE ENTOMOLOGIST

Dr. A. W. Drinkard, Jr., Director.

SIR: I have the honor to present herewith a report on the work of the Department of Entomology for the years 1914-15 and 1915-16.

During the years 1912 and 1913 fruit growers in Virginia were much alarmed about the "apple aphis," since many orchards had been injured and much fruit dwarfed and there seemed to be no way of preventing the loss. In attacking this problem it was necessary to find out which of the several species found on the apple was responsible for the injury and to make a study of their biology, for at the outset all of the aphids involved were but slightly known. In addition, studies of the resistance of the insects to insecticides and field spraying experiments were carried on. There are three species of aphides, or plant lice, infesting apple trees, the rosy aphis *(Aphis sorbi Kalt.)* which is found on bearing trees in early summer and which causes the leaves to curl and dwarfs the fruit; the grain aphis *(Aphis avenae Fab.)* which is usually very numerous at the time apples are in blossom; and the green apple aphis *(Aphis pomi De G.)* which occurs on young trees and the succulent growth of older trees. These three species may be controlled and injury prevented by spraying the trees with a nicotine spray at the time growth starts and when the newly hatched lice are clustered on the green tips.

The peach yellows problem which was started several years ago is being continued. The physiology of the diseased and healthy trees has been studied and inoculations made to determine if the malady can be transmitted in this manner.

The truck crop insect investigations were carred on at Norfolk in coöperation with the Truck Experiment Station. The work consisted mainly of field experiments to determine a practical method of control for the more important truck crop pests accompanied by detail life history studies of several lesser known species. The problems of insect control that confront the majority of vegetable growers constitute a neglected phase of entomological research. The following paragraphs contain a brief report of the work.

The green pea aphis (*Macrosiphum pisi* Kaltenbach) has been causing serious injury to peas since 1899 with the result that many growers have stopped producing this crop for commercial purposes. The life history and habits of this pest have been carefully studied; various remedies have been tried, some with good results. The first season's spraying experiments were published as Bulletin No. 13 of the Truck Experiment Station. The life history studies were published as a part of the Tenth Report of the State Entomologist, pp. 32-63.

The use of insecticides on potatoes has become general in the trucking section and in order that growers may have information regarding the value of the proprietary materials as compared with the standard remedies, experiments are performed each year. The comparison of the insecticides is made by a determination of their efficiency in killing the adult and

larval beetles and by the yields of potatoes. The dust and liquid methods are also being investigated.

The potato aphis (*Macrosiphum solanifolii* Ashm.) is confused with the pea aphid by the majority of people. It attacks potato, asparagus, egg-plant, peas, clover, and a long list of other plants. Owing to the large acreage of potatoes in the region of Norfolk and the possibilities that aphids have for rapid increase in numbers this insect may assume tremendous importance at any time. Its control is being investigated.

There are several species of flea beetles which cause considerable damage to truck crops and during the season of 1914 several hundred acres of corn near Norfolk were destroyed by these insects. The following three are the most important species: *Epitrix parvula* Fab., E. *cucumeris* Harris, *Choetocnema confinis* Lec. Injuries have been noted on corn, potatoes, egg-plants, tomatoes, sweet potatoes, tobacco, cabbage, cucumbers, melons and squashes. The greatest injury occurs during hot, dry weather. These insects were studied as occasion would permit. Various sprays were tried with poor success. Paris green and slaked lime dusted on the plants acted as a repellant as well as a direct poison.

The sumac flea beetle (*Blepharida rhois* Foster), about which very little is known, has been studied and remedial measures suggested.

The pavement ant (*Tetramorium cespitum* L.) has been the cause of more or less serious loss to various cold-frame, hot-bed, and green-house crops. The problem of its control under these conditions has not previously been worked out. The results of experiments against this pest were published in Bulletin No. 16 of the Truck Experiment Station.

The Entomologist wishes to state that the funds available for investigation in entomology are not sufficient to meet even the most pressing needs of the fruit grower and farmer, and that there is a large class of insect problems that cannot even be touched. The insect damage to stored grains and to manufactured products is enormous. The loss sustained in flour mills, due to the work of the Mediterranean flour moth, the Indian meal worm, and similar pests is considerable. Such insects as mosquitoes and house flies merit investigation. The industry of bee keeping—which should yield an annual income to the state of Virginia of several millions of dollars—has received no attention.

Respectfully submitted,

W. J. SCHŒNE, *Entomologist.*

REPORT OF THE DAIRY HUSBANDMAN

Dr. A. W. Drinkard, Jr., Director.

SIR: I have the honor to submit the report for the Department of Dairy Husbandry.

Two experiments on feeding dairy cows were continued in coöperation with the Department of Chemistry.

One experiment deals with the determination of the protein and energy requirements for milk production. A preliminary feeding period of ten days was begun April 20, 1916, with six cows, for the purpose of determining their basal feeding requirements. These requirements were determined and the feeding period of 150 days was started. The feeding trial consisted of twelve ten-day feeding periods and three ten-day digestion trials, in which the rations were interchanged and re-adjusted as outlined in the project. After this a maintenance trial for ninety days, with two ten-day digestion trials included, was conducted with three of the cows, for the purpose of determining their actual maintenance requirements. Heretofore, Armsby's Standards have been used for this purpose. These data will be submitted for publication in the near future.

The other experiment deals with the physiological effects of wide and narrow rations on cows and on their progeny. The experiment was continued as outlined, and in addition it was found necessary to secure more complete data in regard to the growth and metabolism of the animals. A digestion trial was made with one cow of each group. The system of measurements was made more complete by increasing the number of body measurements of the individuals and measuring more frequently. The results of the digestion trial of this experiment are given in this report.

Respectfully submitted,

C. W. HOLDAWAY, *Dairy Husbandman.*

REPORT OF THE ANIMAL HUSBANDMAN

Dr. A. W. Drinkard, Jr., Director.

SIR: I have the honor to submit the following report from the Department of Animal Husbandry.

1. *Wintering Steers.*—The feeding experiments to determine the best winter ration when the following summer gains are taken into considera-

tion, show that the rations employed rank in the following order for steers finished as three-year-olds according to the two years' work completed:

Lot	1—40	pounds	silage,	alone		
"	2—35	"	"	1	pound	cotton-seed meal
"	3—40	"	"	1	"	" "
"	4—30	"	"	1	"	" "
"	5—20	"	stover	1½	"	corn

The above rations show the amount and kind of feed that was fed each steer in the respective five lots every day. The rations have been changed for this year's work, and they are:

Lot	1—40	pounds	silage			
"	2—45	"	"			
"	3—40	"	"	5	pounds	hay
"	4—40	"	"	5	"	straw
"	5—40	"	"	5	"	stover

2. *Supplemental Feed for Steers on Grass.*—The supplementing of grass pastures with one, two, three and four pounds of cotton-seed meal per head per day to three-year-old fattening steers on Virginia blue-grass pasture, showed that when pastures are good and the steers are not limited in their grazing, pasture alone gives greater gains. This experiment is to be continued, using corn alone, corn and cotton-seed meal, and cotton-seed meal as supplemental feeds.

3. *Wintering Dairy Heifers.*—Wintering of dairy heifers during the first year showed that cotton-seed meal and silage are equal to clover hay and corn meal, or a combination of the two rations, and was much more economical under our present conditions. This project is being carried on this winter as a comparison of certain concentrates with silage as the sole roughage. The concentrates being used are cotton-seed meal, linseed meal (old process), bran, and peanut meal.

Respectfully submitted,

R. E. Hunt, *Associate Animal Husbandman.*

REPORT OF SUPERVISOR OF COUNTY STATIONS

Dr. A. W. Drinkard, Jr., Director.

Sir: I have the honor to submit herewith a report of the work at the several County Stations.

There are nine County Stations, three of which are financed by the State Board of Agriculture, and are located at Staunton, Charlotte, and

Martinsville; and six are financed from State appropriations, and are located at Holland, Williamsburg, Bowling Green, Louisa, Appomattox, and Chatham.

The chief reasons which led to the adoption of the policy of establish ing County Experiment Stations were, first, the comparative inaccessibility to many farmers, of the State Experiment Station at Blacksburg; and secondly, the great differences in soil types and climatic conditions in the several regions of the State, which make it impossible to do experimental work on all crops at the same place. Annual field days are held at these County Stations when large numbers of farmers assemble to avail themselves of the opportunity to become acquainted with the experiments and hear lectures by experts on different agricultural subjects.

The County Station work is very important, and it is hoped that the legislature and State Board of Agriculture will increase their appropriations in order that the number of County Stations may be increased, thereby allowing the work to be carried on in other counties.

Chatham, Pittsylvania County.—Work at this Station has been in progress since 1904. The work consists largely of fertilizer experiments with bright tobacco, studying the residual effect on the crops that follow in the five-year rotation. The use of lime in connection with the different forms of commercial fertilizer and its effect on the principal crops of this section are studied. A set of plats of one acre each is used as demonstration plats, on which the proper methods of crop rotation, fertilization and cultivation are used. Variety tests of corn and tobacco are conducted each year. A field meeting is usually held in August and these annual meetings are well attended, the farmers of the county having opportunity to see the experimental results in the field. The experiments here have proved it inadvisable to grow leguminous crops in the rotation where fine bright tobacco can be grown; still there is no excuse for the one-crop system which commonly prevails in this section. By laying out a portion of the farm and using a rotation of tobacco, small grain and herd's grass, the remainder of the land may be brought to a high state of productivity by the use of grasses and leguminous crops. This is shown by the bountiful yields of hay and grain where this method is followed. J. C. Hart is in charge.

Appomattox, Appomattox County.—The main lines of work conducted at Appomattox during 1915 were essentially the same as those carried on when the last report was made, that is, the fertilizer tests on tobacco and crops grown in rotation with tobacco. Also the crop rotation work was practically the same.

During the season of 1916 some changes were made and additional projects were initiated. One change was in the crop rotation. Previous to

this season the crop rotation was in this order: Tobacco, wheat, grass (two years), corn, followed with crimson clover at the last cultivation, cowpeas or soybeans, tobacco. For some cause the tobacco did not seem to grow off well following peas and beans. Hence this season it seemed wise that another rotation be started. Now it is conducted as follows: Tobacco, wheat, grass (two years), and tobacco again the fifth year. Excellent results were obtained the first season with tobacco following grass. In the previous system of rotation six plats were required, in the latter only four plats, hence in the other two plats the following rotation is being tried: Soybeans, land seeded to rye and crimson clover after beans are harvested; second season this rye and clover is fallowed and corn planted; after the corn is harvested, rye is seeded for a fallow crop for soybeans.

The variety tests include soybeans, cowpeas, potatoes, and tobacco. Tests with soybeans and cowpeas were conducted with the idea of finding out the best and most prolific varieties for this section. In potato tests, the aim was to find out the best late variety for this section. No report was made on tobacco variety test. The season being very wet, cowpeas made a very vigorous growth of vine, but did not set much fruit. Soybeans did very well. The season was very dry and therefore unfavorable for late potatoes. A variety test of alfalfa was started in the fall of 1916. At this writing the stand is good. Some interesting and instructive results are expected from the alfalfa test. B. G. Anderson is in charge.

Louisa, Louisa County.—This work was begun in 1908. No experiments have been conducted here for three or four years, but acre plats of tobacco, wheat, hay grasses, corn, cowpeas and crimson clover have been grown to demonstrate the best results secured from the crop rotation and fertilizer experiments, at Bowling Green, and from similar results at this place, which has resulted in satisfactory and constant building up of the soil most effectively. Work at this station was discontinued entirely with the 1916 results. W. W. Green is in charge.

Bowling Green, Caroline County.—The U. S. Department of Agriculture, in coöperation with the Experiment Station, undertook certain experiments at this place in 1908, which have been continued to the present time. In conducting these experiments especial attention has been directed to fertilization, cultural methods, combating insects, varieties of tobacco and other crops grown in rotation with tobacco. These experiments indicate that for tobacco heavy applications of a complete fertilizer analyzing about 4-10-6 are most profitable. Experiments with varieties of tobacco indicate that the small strains of Oronoco are best suited to the sun-cured section. Results seem to have proved conclusively that the most effective means of destroying the horn-worm on tobacco is with a proper application of arsenate of lead made with the most modern dust gun

(Monarch). Other experiments pertaining to alfalfa made more recently by us seem to verify the theory that heavy applications of acid phosphate. lime and inoculation are essential to successful alfalfa growing in this section. W. W. Green is in charge.

Holland, Nansemond County.—The main object of this station is to work with cotton and peanuts in rotation with other crops. These are the principal crops of this section of the state. A four-year rotation was selected consisting of cotton, corn, peanuts and soybeans, with corn and soybeans seeded to crimson clover to be turned down the following spring. Special attention is given to fertilizer work under cotton. Results thus far seem to indicate that acid phosphate has a tendency to cause hulls to form and mature earlier, also that nitrogen in very large quantities acts just the reverse way, and keeps the plant growing late thus interfering with maturity before frost.

Variety work, also, is done with cotton. On account of the very short growing season for this crop in Virginia, it is desirable to use the variety which will mature in the shortest time. The long staple varieties of cotton have shown up very poorly up to this time. With peanuts, the greater part of the work is with lime and other substances containing calcium, which element, it seems, is a very important factor in giving the peanuts good weight and at the same time giving the hulls a light color which is very important when the crop is marketed. Several varieties are used, in cluding Virginia Bunch, Virginia Runner, Jumbo, Valencia and Spanish. E. T. Batten is in charge.

Williamsburg, James City County.—Operations were begun at this station in 1912. Experiments are now under way testing methods of fertilizing alfalfa, both previous to seeding and as top dressing, liming, methods of cultivation and tests with varieties of alfalfa. The fertilizer tests have shown most strikingly the value of phosphorus in relation to alfalfa growing in this section. Acid Phosphate and barnyard manure, applied at the rate of 10 tons of barnyard manure and 400 pounds of 16% acid phosphate per acre, have given the most satisfactory results. In all tests of fertilizers. from commercial sources, for alfalfa, phosphorus is shown to be the controlling factor. Yearly top dressings to alfalfa with commercial fertilizer, early in the spring after the first season, have been found to greatly strengthen the plants, making the growth more rapid and dense, thereby keeping the ground shaded and preventing development of grass and weeds. It is not yet fully determined but we have reason to believe phosphorus to be the controlling factor in top dressing as well as in applications previous to seeding.

The tests with the varieties of alfalfa have been most interesting to the alfalfa growers of this section. The behavior and finally the complete

dying out of the Turkestan variety gives explanation for the majority of the failures in alfalfa growing in Eastern Virginia. The tests have shown the American varieties to be superior to any of the imported varieties, and of these the Kansas grown seed are giving the best results. The lime tests embracing the use of burnt and ground limestone, in varying amounts from one to four tons of burnt lime and from two to eight tons of ground limestone per acre, have as yet given no conclusive results in increasing the yield of alfalfa. Experiments are also being made to determine the relative value of leguminous crops turned in the soil as compared with barnyard manure as fertilizer for alfalfa. R. P. Cocke is in charge.

Charlotte Court House, Charlotte County.—This experimental work was begun at Charlotte Court House five years ago, under the supervision of the Virginia Experiment Station, for the State Board of Agriculture. The site selected for the experiment plats was exhausted soil, being very poor and devoid of humus. Some of the land had been cultivated many years and had reached the stage where it would produce practically nothing. A good rotation was begun at once and by the use of a complete fertilizer to start the crops, followed by green manures and applications of lime, wonderful improvement as well as splendid results have been obtained. Special attention is given to tobacco culture in rotation with wheat, grass, corn and cowpeas.

In view of what had been done in regard to soil improvement, more land was taken up, this piece containing about 15 acres. This land has long been idle, and is characterized as worn-out soil, being much overgrown with bushes and broom-sedge. This land will be improved with green manure crops and by the use of acid phosphate and lime. The experiments carried on at this station have clearly demonstrated that the so-called "worn-out" lands of the region have great possibilities for agricultural use, and by judicious fertilization, soil management and crop rotation, these lands can be made productive and profitable. A. P. Moore is in charge.

Staunton, Augusta County.—This station is supervised by the Experiment Station for the State Board of Agriculture. The main lines of work are crop rotations, soil fertility and variety experiments. A five-year rotation of corn, soybeans, wheat and grass (two years) is used, on which an extensive series of fertilizer experiments is conducted. Especial attention is given to a comparison of different sources of phosphoric acid and nitrogen, and the various forms of lime. Another five-year rotation is used consisting of corn, wheat (two years), and grass (two years)—a rotation on which various mixtures of commercial fertilizers are tried in comparison with home-mixed goods of the same formulas.

Varieties of wheat and corn are being tried out. Rates and dates of seeding wheat and fall *versus* spring applications of fertilizers to wheat are being tested. The results of the work in alfalfa seem to justify the statement that it is more profitable to sow a light rather than a heavy rate of seed per acre, that is, about fifteen pounds instead of thirty. Also, that it is more profitable to sow alfalfa alone than in a mixture, and, that if alfalfa can be grown successfully, it is more profitable than any other hay crop. This experiment farm is favorably situated for the purpose, and should be of distinct service to agriculture in the Valley region of the State. J. M. Trimble is in charge.

Martinsville, Henry County.—The work at this station is conducted by the Virginia Experiment Station for the State Board of Agriculture. Special attention has been given to a comparison of various crop rotations. There are three distinct rotations under comparison, namely, two-year, three-year, and five-year rotations. The two-year rotation consists of corn and cowpeas with crimson clover, rye and vetch seeded at the last cultivation of the corn. The three-year rotation consists of corn, wheat and sapling clover. A fertilizer test is conducted with each of these rotations and the results from both indicate that next to stable manure this soil needs acid phosphate.

The five-year rotation consists of corn, soja beans, oats, and grass (two years). This land receives no application of fertilizer, as the plats were arranged for the purpose of ascertaining the improvement of the land by the rotation of crops.

A number of variety tests are being conducted, including tests of corn, wheat, winter and spring oats, cowpeas, soy beans, and potatoes. This work has not yet progressed far enough to warrant the selection of certain varieties as the best for this section of the State. Sudan grass is experimented with in order to ascertain its adaptation to the locality, the best date and rate of seeding, and method of seeding. It grows well when seeded in rows about May 1, and cultivated. When seeded broadcast the weeds and foul growth choke it out. A small portion of land is devoted to the growing of unfamiliar crops for both their educational and practical value. These crops include velvet beans, kaffir corn, shaller, peanuts, millet, buckwheat, rape, teosinte, sunflowers, sorghum, maize, feterita, and pop corn. On a much larger scale are grown fields of wheat, oats, barley, and rye.

Nine-tenths of an acre is allotted to determining the adaptability of alfalfa to this soil and climate. This was one of the first experiments installed and it has clearly and decisively proved that alfalfa is well suited to this locality. It has averaged a yield for the three years of 4,265 pounds on the nine-tenths of an acre, or 4,692 pounds per acre, or 2.4 tons per acre.

Several grass mixtures have been tried and the best results obtained from up-land seeding consisted of a mixture of Tall Oat Grass, Orchard Grass, and Medium Red Clover.

In addition to the other work at Martinsville, there is now in progress a reclamation project which has attracted considerable attention. This is an effort to reclaim for agricultural purposes a hill-side field that has long been idle. The land in question was thin, badly gullied, and partly covered with scrub pines and other undergrowth. The pines and brush were cut off and thrown into the gullies, the banks of the gullies were blown in with dynamite and leveled by hand labor. The land was partly plowed with a colter plow to cut and break the roots remaining after the undergrowth was removed, and the remainder of the field was plowed with a turning plow. The entire tract was prepared and seeded to cowpeas. The object of this work is to accumulate data on the cost of putting a worn field into such shape that will permit the use of improved farm machinery. This experiment has progressed sufficiently to allow modern machinery to cross every gully. Failing to secure a good stand of grass in the fall of 1916, the land was thoroughly disced and rye was seeded over the entire area. At the time of writing this article, the rye stands about one foot high and is ready to be turned under. A. N. Hodgson is in charge.

Respectfully submitted,

E. R. Hodgson, *Supervisor.*

REPORT OF THE LIBRARIAN

Dr. A. W. Drinkard, Jr., Director.

Sir: I have the honor to submit the following report from the Library for the year ending June 30, 1916. The Library is gradually reaching the standard set. This is largely due to the much needed equipment added, such as shelving and catalogue cases. The Agricultural Index, subscribed for since its appearance, in March, 1916, has been constantly used by all reference workers. Considerable binding has been done each year. The total number of volumes in the Library is 9,327, pamphlets 42,500. A list of periodicals received and filed is given herewith. Periodicals subscribed for by the Station are marked with an asterisk.

List of Periodicals

American Bee Journal
American Breeder
American Fertilizer
American Florist
*American Journal of Botany
American Journal of Veterinary Medicine

*American Naturalist
American Poultry Advocate
American Poultry World
American Sheep Breeder and Wool Grower
*Annals of Applied Biology
*Berichte d. deut. Bot. Gesellschaft
Berkshire World
Better Fruit
*Biological Bulletin
*Biometrika
Black and White Record
*Botanical Gazette
*Botanical Centralblatt
Breeders' Gazette
Buick Bulletin
*Bulletin Soc. Mycolog. de France
California Home and Farmer
Campbell's Scientific Farmer
The Canning Trade
*Centralb. f. Bakteriologie
Chicago Dairy Produce
Cold
Colman's Rural World
*Comptes Rendus
Corn
Cornell Countryman
Country Gentleman
Dakota Farmer
Duroc Bulletin
Elgin Dairy Report
Farm and Fireside
Farm Engineering
Farm Journal
Farm, Stock and Home
Farmers' Digest
Farmers' Guide
Farmers' Home Journal
Farmers' Review
Farmers' Wife
Farming Business
Field and Farm
Flour and Feed
Fruit and Produce Market
Fruit Grower and Farmer
Fruit Trade Journal and Prod. Review
Gas Power
Gleanings in Bee Culture
Good Poultry
Green's Fruit Grower
Guernsey Breeders' Journal
Harvester World
Hoard's Dairyman
Holstein-Friesian World
Horse World
Ice Cream Trade Journal
Independent Farmer
Indiana Farmer
*Jahresbericht f. Agric. Chemie
*Journal of Agricultural Science
*Journal of Amer. Soc. Agronomy
*Journal of Economic Entomology
*Journal of Experimental Zoölogy
*Journal of Genetics
*Journal f. Landwirtschaft
*Journal of Horticultural Society
*Journal of Indus. and Eng. Chemistry
*Journal of Infectious Diseases
*Journal of Royal Agric. Society
Kansas Farmer
*Kryptogamen Flora
*Landwirt. Jahrbücher
*Landwirt. Versuchs-Stationen
Mark Lane Express and Agr. Journal
Market Growers' Journal
Milk Dealer
*Mycologia
National Alfalfa Journal
National Grange Monthly
National Stockman and Farmer
*New Phytologist
New York Produce Rev. and Amer. Creamery
Northern Hort. and Dairyman
Ohio Farmer
Oklahoma Farm Journal
Pacific Dairy Review
Pacific Rural Press
*Phytopathology
*Plant World
Practical Farmer
Prairie Farmer
Progressive Farmer
Reliable Poultry Journal
Sand Farmer
Show Horse Chronicle
Southern Farm and Dairy
Southern Field
Southern Fruit Grower
Southern Planter
Southern Progress
Southern Ruralist
Southwest Trail
Successful Farming
Successful Poultry Journal
Texas Stockman and Farmer
Threshermen's Review and Power Farming
Up-to-date Farming
Useful Poultry Culture
Utah Farmer
Vegetable Grower
Vertical Farming
Wallaces' Farmer
Washington Farmer
Western Empire
Western Farm Life
*Zeitschrift f. Botanik
*Zeitschrift f. Pflanzenkrankheiten
*Zeitschrift f. Physiol. Chemie

Respectfully submitted,

Anna E. Murrill, *Librarian.*

THE EFFECTS OF HIGH PROTEIN AND HIGH ENERGY RATIONS IN FEEDING DAIRY COWS

PART I.—EFFECTS ON THE UTILIZATION OF THE RATIONS

By W. B. ELLETT AND C. W. HOLDAWAY*

The experiments, of which the work described in this bulletin is a part. were planned for the purpose of paralleling other feeding experiments conducted at this station, and of ascertaining what would occur when abnormal feeding conditions in regard to protein and energy content of rations were imposed upon dairy cows. E. Pflüger (1) states that the addition of protein to a maintenance ration caused an increase in metabolism and the productive power. Further, it caused an increase in the body weight due to an increase in cell substances. This increase of cell substance under favorable conditions could be induced until the body weight was doubled. Metabolism and productive power of the body increased in direct proportion to the increase in body weight induced by protein. The highest metabolism and the greatest productive power could therefore be induced only by the most abundant supply of nitrogen in the food. Each diminution of the daily supply of protein caused a decrease in the metabolism and productive power, even if the protein omitted was replaced by an amount of fat and carbohydrates calculated to supply the same amount of energy.

It has been contended among dairymen (2) that an increase of protein in rations already containing a sufficient amount for dairy cows acts as a stimulant to extreme production. This contention is based upon the assumption that most dairymen who secure high records feed large amounts of protein.

Problems Involved in These Experiments.—The feeding of excess protein to dairy cows for long continued periods might be injurious to the health of the cows. It might also affect the growth and development of the offspring. Physiological derangements might be induced in both cows and offspring. This method of feeding might also affect the composition and milk yield of the cows and also of the offspring, if they remained on the same rations as were given their dams. Metabolic variations in the digestibility and general utilization of the nutrients of the rations would probably occur.

*The authors are indebted to W. G. Harris for his assistance in calculating the tabular matter.

On the other hand, very many farmers expect cows to produce milk and thrive on rations which do not contain sufficient protein in concentrated form. Hence the cows have to eat large amounts of the feed to secure enough protein for their requirements. The results of such feeding form an interesting study, especially when compared with the results secured with the excess protein ration.

The data given in the following experiments compare these two rations in their effects on the metabolism and use of the rations as food by dairy cows. This comparison forms one of the most interesting features of the investigation and throws light on many of the obscure points involved. Yearly digestion trials are made with one animal from each group and the results of the first of these trials are given here.

The Animals.—Four cows were selected for this experiment and divided into two groups. They were all pure bred Holsteins, closely related and the grouping was balanced as closely as possible with respect to all visible and measurable characteristics.

The Rations.—One group received a ration consisting of 9 pounds of corn meal, 2 pounds of bran and 40 pounds of silage. This ration is designated as the High Energy Ration, and has a nutritive ratio of 1:11.0. The other group received what is designated as the High Protein Ration, which consisted of 2 pounds of cottonseed meal, 2 pounds of bran, 7 pounds of corn gluten meal and 40 pounds of silage. This has a nutritive ratio of 1:2.4. Both rations supply the full necessary amounts of nutrients for maintenance and milk production, but the first contains an excess of energy and the second an excess of protein.

The complete experiment was started in 1913, but the cows were not fed continuously on the rations until September, 1915. Since that time the rations have been fed continuously and the same conditions with respect to exercise and handling have been imposed on all the animals.

EFFECTS OF HIGH PROTEIN AND HIGH ENERGY RATIONS ON UTILIZATION OF RATIONS*

The composition of the food stuffs used in the rations in terms of percent of total constituents is given in Table I.

Tables II and III show the amounts actually fed and consumed in the ten-day period.

The amounts of digestible protein and net energy in the food consumed daily were calculated from these figures, using average digestion coefficients from Henry and Morrison (3) and Kellner's (4) production values. The requirements for maintenance and milk production were calculated by using Armsby's methods (5). The results are given in Table IV.

It can be seen from Table IV that the High Energy cow was not consuming quite enough feed to supply her with the necessary protein as calculated from average digestion factors. On the other hand the energy as

TABLE I.—*Analyses of Food Stuffs*

Food	Moisture	Fat	Crude Fiber	Nitrogen	Protein	Ash	Nitrogen-Free-Extract
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Cottonseed Meal	8.31	6.35	11.03	6.153	38.46	6.27	29.58
Gluten	11.50	.37	2.91	7.294	45.59	1.03	38.60
Bran	11.09	2.97	10.71	2.230	13.94	6.71	54.58
Corn Meal	13.48	3.77	1.96	1.414	8.84	1.21	70.74
Silage	76.63	.55	6.91	0.292	1.83	1.37	12.71

TABLE II.—*Actual Food and Food Constituents Fed*
(In pounds)

Group	Amount Fed		Dry Matter	Ash	Protein	Crude Fiber	Nitrogen-Free-Extract	Fat
	Grain	Roughage						
High Energy Ration	110	400	189.130	7.911	18.064	31.546	125.422	6.187
High Protein Ration	80	300	141.451	6.571	36.145	25.447	70.054	3.234

*The study of this section of the work will be continued with these and other animals on the experiment and also with the offspring as they come into milk. The conclusions will therefore be subject to modification as the data accumulate.

TABLE III.—*Food and Constituents Consumed*

Group	Feed	Grain	Roughage	Dry Matter	Ash	Protein	Crude Fiber	Nitrogen-Free-Extract	Fat
High Energy Ration		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
	Corn	90		77.868	1.089	7.956	1.764	63.666	3.393
	Bran	20		17.782	1.342	2.788	2.142	10.916	0.594
	Silage		400	93.480	5.480	7.320	27.640	50.840	2.200
	Total Fed	110	400	189.130	7.911	18.064	31.546	125.422	6.187
	Waste		34.5625	7.189	0.356	0.442	2.641	3.691	0.059
	Net Consumed	110	365.4375	181.941	7.555	17.622	28.905	121.731	6.128
High Protein Ration	Cottonseed Meal	15.00		13.754	0.940	5.769	1.655	4.437	0.953
	Bran	50.00		44.250	0.515	22.795	1.455	19.300	0.185
	Gluten	15.00		13.337	1.006	2.091	1.607	8.187	0.446
	Silage		300	70.110	4.110	5.490	20.730	38.130	1.650
	Total Fed	80.00	300	141.451	6.571	36.145	25.447	70.054	3.234
	Waste	5.75		3.730	0.118	0.811	0.263	2.463	0.075
	Net Consumed	74.25	300	137.721	6.453	35.334	25.184	67.591	3.159

TABLE IV.—*Requirements for Maintenance and Milk Production and Amounts Consumed Daily, in Pounds Digestible Protein and Therms Net Energy*

Group	Maintenance Per Day*		Maintenance and Milk Production Per Day	
	Digestible Protein	Net Energy	Digestible Protein	Net Energy
Requirements of High Energy Cow	0.5	6.0	1.13	9.08
Requirements of High Protein Cow	0.5	6.0	1.13	10.14
Amounts Consumed by High Energy Cow			1.101	12.908
Amounts Consumed by High Protein Cow			2.797	8.976

*Both cows calculated at normal weight of 1,000 pounds.

calculated is very high. The High Protein cow had the reverse conditions to contend with, of excess protein and hardly enough energy.

These two cows at the beginning of the feeding period, eight months earlier, had been fed the full amounts of the rations and in both cases there was then sufficient protein and energy for their needs, the difference being

that in the case of the high energy ration there was too much energy, and in the high protein ration too much protein. In both cases much care had to be exercised in feeding, as the cows had the tendency to go off feed and it was necessary in order to feed to the limit, to restrict the amount of feed at the first sign of trouble. Later, the animals corrected this themselves. the High Protein cow generally refusing grain, the High Energy cow, roughage. In other words, the body adjusted itself to the conditions imposed. Therefore at the beginning of this digestion trial the High Protein cow was eating only about three quarters of her full ration and the High Energy cow ate all but a very small amount of hers.

Condition of Animals.—When the digestion trial began, the High Protein animal was rounded and firm of flesh, and the High Energy animal extremely emaciated, but she has now gone into another lactation period without change of feed.

Weights of Cows.—The weights of the cows are given in Table V. Both are 1000 to 1050-pound cows. The table shows that at the time of the digestion trial the High Energy cow was at her minimum weight. The High Protein cow gained weight after the trial, as did the High Energy cow, but they were rapidly drying off and the nutrients were evidently being used for the growth of the foetus.

TABLE V.—*Weights of Cows Monthly before and after the Digestion Trial and Daily During the Trial*

DATE	HIGH ENERGY COW	HIGH PROTEIN COW
	Pounds	*Pounds*
Nov. 1, 2, 3, 1915	993*	1,029
Dec. 1, 2, 3, 1915	954	1,009
Jan. 1, 2, 3, 1916	916	1,012*
Feb. 1, 2, 3, 1916	894	1,023
Mar. 1, 2, 3, 1916	886	1,057
Apr. 1, 2, 3, 1916	884	1,031
Digestion Trial		
Apr. 24	890	1,057
25	907	1,064
26	900	1,051
27	910	1,035
28	906	1,055
29	922	1,068
30	896	1,054
May 1	899	1,043
2	892	1,050
3	893	1,058
June 1, 2, 3, 1916	930†	1,119†
July 1, 2, 3, 1916	965	1,138

*Date of breeding.
†Showing with calf.

TABLE VI.—*Weights of Dung and Urine, Daily*

Date	High Energy Cow		High Protein Cow	
	Dung	Urine	Dung	Urine
	Grams	*Grams*	*Grams*	*Grams*
Apr. 24	23,586.78	6,350.29	13,380.96	6,350.29
25	24,040.38	3,855.53	12,473.78	6,577.08
26	27,215.52	3,175.14	13,154.17	6,803.88
27	24,947.56	4,762.72	12,020.19	7,030.68
28	25,401.15	3,956.33*	10,432.62	6,879.48*
30	26,761.93	5,443.10	12,020.19	6,803.88
May 1	24,267.17	2,948.35	10,886.21	6,350.29
2	25,401.15	2,494.76	9,752.23	6,803.88
3	27,215.52	2,948.35	12,020.19	7,484.27
4	21,999.21	3,628.74	12,020.19	7,711.06
Total	250,836.37	39,563.31	118,160.73	68,794.79

*Weights of urine for this day were the average of the other nine days.

Digestion Trial.—During the ten days of digestion trial the cows were kept in the stanchions all the time. The mean daily temperature varied between 45° and 60° Fahr. The solid and liquid excrements were collected and analysed for nitrogen daily and composite samples of dung taken for analysis, as a check on the daily determinations. Composite samples of the milk were analysed for the period.

Table VI gives the amounts of dung and urine daily in grams. Comparing the amounts of dung from the two cows, the High Energy cow excreted nearly twice as much as the High Protein cow. The percentage of dry matter in the dung as given in Table VII was the same for both. However, the amount of dry matter eaten by the High Energy cow was 32 percent more than that eaten by the High Protein cow. This in itself is significant and points to a fact that is brought out later, namely, that the High Energy cow was digesting only a small part of her food. The amount of urine, however, was in excess from the High Protein cow, bearing out the statement of Lusk (6) that excess protein causes an increase in the amounts of urine excreted.

Composition of Dung and Urine.—The composition of the dung and urine in Table VII indicates radical differences in the manner of utilizing the rations by the two cows.

The fat and nitrogen-free-extract were highest in the dung of the High Energy cow. This indicates a lowering of the digestibility of these substances. The digestibility of the fat and the nitrogen-free-extract was only slightly decreased.

The percent of nitrogen in the urine from the High Protein cow was three times that of the High Energy cow and since the first named also

TABLE VII.—*Composition of Dung and Urine*

	HIGH ENERGY	HIGH PROTEIN
DUNG—	*Percent*	*Percent*
Dry Matter	15.62	15.90
Moisture	84.38	84.10
Nitrogen	.291	.453
Protein	1.82	2.83
Fat	.38	.31
Crude Fiber	3.64	3.91
Ash	1.18	2.12
Nitrogen-Free-Extract	8.60	6.73
URINE—		
Nitrogen	.627	2.166

TABLE VIII.—*Nitrogen Excreted Daily in Dung and Urine*

DUNG				URINE	
HIGH ENERGY		HIGH PROTEIN		HIGH ENERGY	HIGH PROTEIN
PROTEIN	NITROGEN	PROTEIN	NITROGEN	NITROGEN	NITROGEN
Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
540.14	86.33	452.28	72.39	28.07	133.55
557.74	89.19	412.88	65.99	27.91	154.56
593.30	94.71	353,85	56.69	26.48	156.97
561.32	89.81	415.90	66.47	21.72	148.42
497.86	79.76	378.70	60.51	24.82*	148.98*
626.23	100.09	437.53	70.08	24.28	150.84
482.92	77.17	339.65	54.32	23.00	148.03
490.24	78.24	342.30	54.71	23.75	146.83
514.37	82.19	395.46	63.35	23.35	153.13
464.18	74.36	391.86	62.75	24.82	148.52
5,327.30	851.85	3,920.41	627.26	248.20	1,489.83

*Weights of nitrogen in the urine for this day were the average of the other nine days.

TABLE IX.—*Analysis of Milk*

	Specific Gravity	Percent of Constituents						
		Fat	Sugar	Nitrogen	Protein	Ash	Total Solids
High Energy Cow—							
First Five Days	1.028	2.9	4.40	.434	2.77	.80	11.15
Second Five Days	1.028	3.0	4.45	.439	2.80	.68	11.09
High Protein Cow—							
First Five Days	1.032	4.4	4.20	.577	3.68	.69	13.84
Second Five Days	1.030	4.6	4.30	.561	3.58	.77	13.97

TABLE X.—*Daily Nitrogen Balance*

	Day	Nitrogen in Dung	Nitrogen in Urine	Nitrogen in Milk*	Total	Total Nitrogen Consumed in Feed	Nitrogen Balance
		Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
High Energy Ration	1	86.33	28.07	29.12	143.52	123.56	
	2	89.19	27.91	27.76	144.86	123.56	
	3	94.71	26.48	28.53	149.72	128.14	
	4	89.81	21.72	27.58	139.11	129.55	
	5	79.76	24.82	26.40	130.98	128.64	
	6	100.09	24.28	26.49	150.86	128.64	
	7	77.17	23.00	25.90	126.07	128.41	
	8	78.24	23.75	24.49	126.22	130.04	
	9	82.19	23.35	24.09	129.63	128.87	
	10	74.36	24.82	25.90	125.08	128.19	
	Total	851.85	248.20	266.26	1,366.31	1,277.60	–88.71
High Protein Ration	1	72.39	133.55	33.25	239.19	249.43	
	2	65.99	154,56	32.21	252.76	250.70	
	3	56.69	156.97	31.93	245.59	257.10	
	4	66.47	148.42	32.70	247.59	262.22	
	5	60.51	148.98	31.39	240.88	262.22	
	6	70.08	150.84	30.53	251.45	262.22	
	7	54.32	148.03	27.99	230.34	254.56	
	8	54.71	146.83	27.49	229.03	259.68	
	9	63.35	153.13	28.76	245.24	262.22	
	10	62.75	148.52	30.03	241.30	241.76	
	Total	627.26	1,489.83	306.28	2,423.37	2,562.11	+138.74

*Used 5-day composite samples of milk.

excreted fifty percent more urine, this indicates a very great difference between the two cows in the metabolism of protein in the rations.

Grams of Nitrogen in Dung and Urine.—Table VIII gives the grams of nitrogen and protein excreted in the dung and urine daily. Although the percent of nitrogen was lowest in the dung of the High Energy cow, the actual grams of nitrogen excreted daily were highest. Thus, although the High Energy cow was consuming only one third the amount of nitrogen that was being consumed by the High Protein cow, she was excreting more by weight in her feces, indicating a great reduction in the amount of protein digested. The amounts of nitrogen excreted in the urine show the difference between the two animals in protein metabolism, one being six times as great as the other.

Amounts and Composition of Milk.—The percentage composition of the milk is given in Table IX. No discussion of the effects of these rations on the amount and composition of the milk will be given here, since the differences in the table may possibly be due to the individuality of the cows. Data bearing on this point are now being collected.

Nitrogen Balance.—The tables dealing with the distribution of nutrients in feed, excrements and milk have been presented on the daily basis for the purpose of verification and comparison. The first of these, Table X, gives the daily nitrogen balance.

The total nitrogen consumed in the feed was twice as much for the High Protein as for the High Energy cow. The High Protein cow excreted twenty-five percent less nitrogen in her dung. Her urine, however, contained six times as much nitrogen.

Taking the total nitrogen in the dung, urine, and milk as 100 percent, Table XI gives the percent of nitrogen found in the dung, urine and milk of each cow. These figures show that the digestion coefficients of the High Energy cow must have been very low. They also indicate what occurs generally when two such extreme rations are fed.

Referring again to the nitrogen balance for the period, the average daily nitrogen loss for the High Energy cow was 8.87 grams, equivalent to 0.5 pounds of flesh (7). Her daily weights indicate a greater loss than this. The High Protein cow was gaining 13.9 grams of nitrogen, equivalent to 0.8 pound of flesh, but her daily weights did not show any gain. However, by referring to Table V, which gives the weights of the cows before and after the digestion trial, it will be seen that this latter cow was gaining weight at a higher rate than is indicated in the nitrogen balance. Daily weighings over short periods are poor indications of an animal's gain or loss of body flesh.

Another point of interest in the nitrogen balance is that the High Energy cow actually had a daily surplus of only 0.21 pound of digestible protein left over for body maintenance. But she was not maintaining her weight by nearly 0.1 pound of protein daily, as shown by the nitrogen bal-

ance. Under her conditions then, the amount of digestible protein for maintenance would be at least 0.31 pound daily, while Armsby's standard is given as 0.5 pound.

Although the High Protein cow had been refusing grain continually and actually had consumed four times as much protein as was necessary for body maintenance, yet she was not in nitrogen equilibrium, as can be seen, but was gaining in flesh. Voit's (8) experiments on a dog show that

TABLE XI.—*Percent of the Total Nitrogen in Excrements and in Milk*

	DUNG	URINE	MILK
High Energy	62.35	18.75	19.48
High Protein	25.88	61.48	12.64

continued increase in the protein ingested tends to establish nitrogen equilibrium at higher and higher levels, but this cow with this large amount of surplus protein on a mixed diet, had not attained equilibrium.

Table XII deals with the weight of the different constituents, other than nitrogen, in the feed, dung and milk each day. The digestion coefficients are estimated from this and the preceding table.

In Table XII the differences between the fat in the feed and that found in the dung and milk for both cows should be noted. The fat in the milk and dung from the cow that was fed the high energy ration is equal to that in the feed. The two practically balance each other. The cow that was fed the high protein ration on the other hand, produced in her milk 98.64 grams more fat daily than was in her food. This is over 40 percent of the total fat of the milk and its source must have been either protein or carbohydrates or both. Jordan (9) also has shown that milk fat may be produced from other substances than food fat.

The rations as originally worked out were based on average digestion coefficients. Table XIII gives the average and actual digestion coefficients for the two cows.

Reduction of the digestibility of rations due to the so called wideness or lack of protein has been noted many times by observers. Van Ewing (10) in feeding a steer on silage alone obtained results similar to the above except in respect to crude fiber. His results for this constituent were quite up to the average while these results show that the crude fiber is affected more than any other constituent. Kellner (11) also mentions the fact that digestibility is lowered with ruminants when less than 1 part digestible crude protein is fed to every 8 parts of digestible non-nitrogenous nutrients.

TABLE XII.—*Constituents in Feed, Milk and Dung, Daily*

Ration	Day	Dung: Nitrogen-Free-Extract	Dung: Fiber	Dung: Fat	Milk: Fat	Milk: Sugar	Feed: Nitrogen-Free-Extract	Feed: Fiber	Feed: Fat
		Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	Grams
High Energy Ration	1	2,028.46	858.56	89.63	194.68	295.38	5,301.49	1,153.67	274.47
	2	2,067.47	875.07	91.35	185.47	281.41	5,301.49	1,153.67	274.47
	3	2,340.53	990.64	103.42	190.74	289.39	5,540.67	1,324.76	278.28
	4	2,145.49	908.09	94.80	184.16	279.41	5,616.38	1,378.92	279.46
	5	2,184.50	924.60	96.52	176.27	267.44	5,567.93	1,344.27	278.69
	6	2,301.53	974.13	101.70	180.98	268.48	5,567.93	1,344.27	278.69
	7	2,086.98	883.32	92.22	176.90	262.40	5,555.82	1,335.60	278.51
	8	2,184.50	924.60	96.52	167.38	248.30	5,640.60	1,396.25	279.87
	9	2,340.53	990.64	103.42	164.65	244.26	5,580.04	1,352.93	278.91
	10	1,891.93	800.77	83.60	176.90	262.40	5,543.71	1,326.94	278.32
	Total	21,571.92	9,130.42	953.18	1,798.13	2,698.87	55,216.06	13,111.28	2,779.67
High Protein Ration	1	900.54	523.20	41.48	253.47	241.95	2,934.69	1,128.36	139.30
	2	839.49	487.72	38.67	245.48	234.33	2,958.96	1,130.94	140.07
	3	885.28	514.33	40.78	243.49	232.42	3,080.43	1,143.87	143.74
	4	808.96	469.99	37.26	249.48	238.14	3,177.59	1,154.26	146.69
	5	702.12	407.92	32.34	239.50	228.61	3,177.59	1,154.26	146.69
	6	808.96	469.99	37.26	250.38	234.05	3,177.59	1,154.26	146.69
	7	732.64	425.65	33.75	229.52	214.55	3,031.85	1,138.70	142.25
	8	656.33	381.31	30.23	225.34	210.65	3,129.01	1,149.08	145.19
	9	808.96	469.99	37.26	235.78	220.40	3,177.59	1,154.26	146.69
	10	808.96	469.99	37.26	246.21	230.15	2,788.96	1,112.80	134.90
	Total	7,952.24	4,620.09	366.29	2,418.65	2,285.25	30,634.26	11,420.79	1,432.21

TABLE XIII.—*Average and Actual Digestion Coefficients*

Constituent	High Energy: Average Coefficient	High Energy: Actual Coefficient	High Protein: Average Coefficient	High Protein: Actual Coefficient
Protein	62.48	33.34	79.21	75.53
Nitrogen-Free-Extract	80.32	60.93	73.66	74.04
Fiber	65.57	30.36	64.84	59.55
Fat	81.26	65.71	77.13	74.42

The digestibility factors for the high energy ration are all low, those for the high protein ration agree closely with the average coefficients. For every 100 pounds of digestible crude protein only 53 pounds were actually digested in the high energy ration, while in the high protein ration 95 pounds were digested. For every 100 pounds of the other digestible nu-

trients the figures are, fiber 46 and 92, nitrogen-free-extract 76 and 100, and fat 81 and 96.

Protein and Energy Values for Maintenance and Milk Production.—In tabulating the protein and energy values in the food consumed and in the milk produced, comparisons are drawn between the results secured by using average and actual digestion coefficients. The therms net energy in the food eaten daily by each cow is given in Table XIV, both coefficients being used. The error that would be made in the results by using average digestion coefficients is shown in this table. When, however, actual coefficients are used the results show that both animals were using the same amount of net energy. This seems to indicate that the High Energy cow could not digest more nutrients than would supply her with the actual energy required and that this is the physiological way that surplus energy in a ration is dealt with by the animal.

Surplus protein, as has been observed here and by many others, is digested, the surplus nitrogen being voided in the urine. This latter fact is illustrated in Table XV, which shows that the high protein cow was digesting much more protein than she needed, while the High Energy cow was not digesting enough for her needs.

Following upon this is Table XVI giving the energy produced in the milk daily from both cows. There was very little difference in the amounts of milk given, the cow fed the high protein ration gave about two pounds less daily. The energy in the milk of the cow fed the high energy ration was 3.724 therms daily. There was 0.28 therm contained in each pound of

TABLE XIV.—*Therms Net Energy in Food Consumed Using Actual Coefficients of Digestion as found (12), and Average Coefficients as Given by Henry (13), and Kellner's Production Values (14)*

Day	Average Coefficients		Actual Coefficients	
	High Energy	High Protein	High Energy	High Protein
1	12.4837	8.6246	8.3713	8.3789
2	12.4837	8.6909	8.3713	8.4382
3	12.9450	9.0226	8.6382	8.7346
4	13.0910	9.2879	8.7226	8.9717
5	12.9975	9.2879	8.6686	8.9717
6	12.9975	9.2879	8.6686	8.9717
7	12.9742	8.8899	8.6551	8.6160
8	13.1377	9.1552	8.7497	8.8531
9	13.0209	9.2879	8.6821	8.9717
10	12.9508	8.2266	8.6416	8.0232
Total	129.0820	89.7614	86.1691	86.9308
Mean	12.9082	8.9761	8.6169	8.6931

TABLE XV.—*Pounds of Digestible Protein in Food Consumed*
(Using actual and average digestion coefficients)

Day	Average Coefficients		Actual Coefficients	
	High Energy	High Protein	High Energy	High Protein
1	1.0647	2.7233	0.5686	2.5968
2	1.0647	2.7373	0.5686	2.6102
3	1.1041	2.8071	0.5897	2.6767
4	1.1166	2.8630	0.5964	2.7300
5	1.1086	2.8630	0.5921	2.7300
6	1.1086	2.8630	0.5921	2.7300
7	1.1066	2.7792	0.5910	2.6501
8	1.1206	2.8351	0.5985	2.7034
9	1.1106	2.8630	0.5932	2.7300
10	1.1046	2.6395	0.5900	2.5169
Total	11.0097	27.9735	5.8802	26.6741
Mean	1.1010	2.7974	0.5880	2.6674

TABLE XVI.—*Energy Produced in Milk, Daily* (15) *(in calories)*
(1,000 calories equivalent to 1 therm)

	Day	Pounds Milk	Energy Protein	Energy Sugar	Energy Fat	Total Energy
High Energy Ration	1	14.8	1,090.60	1,167.80	1,798.52	4,056.92
	2	14.1	1,039.00	1,112.56	1,713.45	3,865.01
	3	14.5	1,068.52	1,144.13	1,762.06	3,974.71
	4	14.0	1,031.55	1,104.67	1,701.30	3,837.52
	5	13.4	987.39	1,057.33	1,628.39	3,673.11
	6	13.3	990.58	1,061.45	1,671.97	3,724.00
	7	13.0	968.24	1,037.42	1,634.26	3,639.92
	8	12.3	916.10	981.65	1,546.26	3,444.01
	9	12.1	901.21	965.69	1,521.12	3,388.02
	10	13.0	968.24	1,037.42	1,634.26	3,639.92
	Total	134.5	9,961.43	10,670.12	16,611.59	37,243.14
High Protein Ration	1	12.7	1,243.28	956.55	2,341.60	4,541.43
	2	12.3	1,203.92	926.42	2,267.84	4,398.18
	3	12.2	1,194.34	918.89	2,249.41	4,362.64
	4	12.5	1,223.60	941.48	2,304.72	4,469.80
	5	12.0	1,174.66	903.82	2,212.53	4,291.01
	6	12.0	1,142.74	925.34	2,313.10	4,381.18
	7	11.0	1,047.51	848.23	2,120.34	4,016.08
	8	10.8	1,028.36	832.81	2,081.79	3,942.96
	9	11.3	1,075.97	871.36	2,178.17	4,125.50
	10	11.8	1,123.58	909.92	2,274.55	4,308.05
	Total	118.6	11,457.96	9,034.82	22,344.05	42,836.83

milk. The High Protein cow's milk had an energy value of 4.284 therms daily or 0.36 therm for each pound of milk.

In Table XVII the amount of energy in the nutrients digested required to produce one pound of the milk is given. For the High Energy cow this is 0.64 therm per pound of milk or 2.32 therms for 1 therm in the milk. For the High Protein cow 2.03 therms for 1 therm in the milk or 0.73 therm per pound of milk. If 6.0 therms were taken off for maintenance for each cow the remaining energy per pound of milk would be 0.19 and 0.23 therms for the two cows respectively. The first figure, 0.19, is very slightly below Armsby's (16) requirements, while the second is 0.06 therm lower. Although these figures and Armsby's agree closely, yet they are much below the actual energy in the milk per pound as calculated in Table XVI, according to Hammersten's energy values for milk constituents. Eckles (17) also noticed this discrepancy in trials at the Missouri Station. It might be well to note here that Armsby's (18) energy allowance in the ration for every pound of milk testing 3.0 and 4.5 percent fat, which is what the milk of these two cows tested, is 0.21 and 0.29 therms respectively, while the energy value per pound as used here is 0.28 and 0.36 therms. By using Armsby's figures for energy for each pound of milk, the net energy available for maintenance would be 5.79 therms for the High Energy cow and 5.2 therms for the High Protein cow, while Armsby's standard for maintenance is 6.0 therms.

Kellner (19) shows that a fat ox requires a larger maintenance ration than a lean one of the same body surface. The conditions of this experiment are hardly comparable to animals on maintenance, but it will be observed that the High Protein cow used the smallest amount of energy for maintenance.

TABLE XVII.—*Net Energy Available for Maintenance, and Comparison between the Energy in Food and in Milk*

	Average Digestion Coefficients		Actual Digestion Coefficients	
	High Energy	High Protein	High Energy	High Protein
	Therms	*Therms*	*Therms*	*Therms*
Net Energy in Food	12.908	8.976	8.617	8.693
Energy in Milk	3.724	4.284	3.724	4.284
Energy Available for Maintenance	9.184	4.692	4.893	4.409
Percent of Energy in Food Available for Maintenance	71.15	52.27	56.78	50.72
Therms in Food to Produce 1 pound of Milk*	0.960	0.757	0.641	0.733

*Obtained by dividing the net energy in the food consumed by the pounds of milk produced.

Table XVIII gives the pounds of digestible protein* available for maintenance for the two cows, the percent of protein in feed available for maintenance, and the pounds of digestible protein in the feed required to produce one pound of milk. First, it is observed that there was an extremely small amount of protein left over for maintenance for the High Energy cow, but as mentioned before she was losing 0.1 pound daily from her body according to the nitrogen balance. The High Protein cow consumed more than four times as much protein for maintenance as was necessary. The other figures are not especially significant in view of the abnormal protein conditions in both cases.

TABLE XVIII.—*Digestible Protein Available for Maintenance*

	Average Digestion Coefficients		Actual Digestion Coefficients	
	High Energy	High Protein	High Energy	High Protein
	Pounds	*Pounds*	*Pounds*	*Pounds*
Digestible Protein in Feed	1.1010	2.7974	0.5880	2.6674
Protein in Milk	0.3745	0.4308	0.3745	0.4308
Protein Available for Maintenance	0.7265	2.3666	0.2135	2.2366
Percent of Protein in Food Available for Maintenance	65.99	84.60	36.31	83.85
Pounds Digestible Protein in Food to Produce 1 pound of Milk*	0.082	0.236	0.044	0.225

*Obtained by dividing pounds of digestible protein in the food consumed by the pounds of milk produced.

SUMMARY

The importance of determining the effects of dissimilar rations in feeding trials can hardly be overestimated. It is fully shown that both high protein and high energy in rations cause results that would introduce inaccuracies in feeding investigations in almost every phase of the work. These inaccuracies would be due mainly to differences in digestibility of nutrients.

The requirements for protein and energy in both cases were supplied by the ration fed when average digestion coefficients were used.

The cow fed the high energy ration consumed almost all of her food and in so doing obtained a large surplus of energy. Her ability to digest the nutrients decreased until the energy dropped to the requirements of her body for maintenance and milk production. Then this decrease in digesti-

*Not "true" protein.

bility stopped. The digestibility of the protein decreased 47 percent, hence the cow was unable to maintain her flesh and decreased in weight rapidly. The reduction in digestibility affected the fiber more than any other non-nitrogenous nutrient. The reduction for fiber was 54 percent, for nitrogen-free-extract 24 percent and for fat 19 percent. The average digestibility of all the nutrients in the ration was 23 percent below the average given by Henry and Morrison.

The High Protein cow refused 25 percent of her ration, but the amount consumed supplied her with sufficient energy and two and one-half times as much protein as was necessary, and this excess protein was digested. The digestibility of the nutrients agreed closely with the average coefficients.

These results show that a cow disposes of an excess amount of digestible protein by digesting it and voiding the excess nitrogen in her urine.

When surplus energy is contained in the nutrients consumed the digestibility of the ration is lowered until the net energy is balanced to the needs of the animal.

The maintenance requirement of the High Energy cow for protein is shown to be at least 0.31 pound daily which is much below Armsby's standard.

The long continued diminution in weight due to lack of protein on one hand and the gaining in weight due to excess of protein on the other hand, indicate a considerable difference in the amounts of nitrogenous material that can be stored up in the mature ruminant's body.

The high protein ration seemed to favor the production of a large quantity of milk fat from substances other than food fat. The food fat exactly balanced the milk and feces fat with the cow fed the high energy ration.

The standards for energy per pound of milk as given by Armsby would be sufficient for these two cows if actual digestion coefficients were used in calculating rations.

LITERATURE CITED

1. Pflüger, E., (Arch. physiol. [Pflüger], 77 [1899], **9-10: 425-482**).
2. Henry, W. A., and Morrison, F. B.—"Feeds and Feeding." p. 350 1915.
3. Henry, W. A., and Morrison, F. B.—"Feeds and Feeding." pp. 653-666. 1915.
4. Kellner, O., trans. Goodwin, W.—"The Scientific Feeding of Animals." MacMillan Co., New York. 1910.
5. Armsby, H. P.—Penn. Exp. Sta. Bul. **114**: pp. 5-6; Bul. U. S. D. A. Bul. **346.** 1909.
6. Lusk, G.—"Elements of the Science of Nutrition." p. 99. 1906. W. B. Saunders Co., Philadelphia, Pa.

7. Fraps, G. S.—"Principles of Agricultural Chemistry." pp. 412-413.
8. Voit, E.—"Stoffwechsel." p. 117. 1881.
9. Jordan, W. H., and Jenter, C. C.—N. Y. Agr. Exp. Sta. Geneva. Bul. **132**: 455-488. 1897.
10. Van Ewing, Perry, and Wells, C. A.—Ga. Agr. Exp. Sta. Bul. **109**: 147-158 (1914), and Bul **115**: 271-298 (1915).
11. Kellner, O—"Ernähr. landw. Nutztiere." p. 51. 1907.
12. See Table XIII.
13. Henry, W. A., and Morrison, F. B.—"Feeds and Feeding. pp. 653-666. 1915.
14. Kellner, O., trans. Goodwin, W.—"The Scientific Feeding of Animals." pp. 353-395. 1910.
15. Hammersten, O., trans. Mandel, J. A.—"Physiological Chemistry." Third edition, p. 554. 1902.
16. Putney, F. S. and Armsby, H. P.—Pa. Agr. Exp. Sta. Bul. **143,** p. 4. 1916.
17. Eckles, C. H.—Missouri Research Bul. **7**: 132-133. 1913.
18. Putney, F. S., and Armsby, H. P.—Pa. Agr. Exp. Sta. Bul. **143**: p. 4. 1916.
19. Kellner, O.—"Ernähr. Landw. Nutztiere." p. 405. 1907.

A TEN-YEAR STUDY OF THE EFFECT OF FERTILIZERS ON THE SOLUBLE PLANT FOOD IN THE SOIL AND ON THE CROP YIELD

By W. B. Ellett and H. H. Hill

In the restoration of depleted soils it has been found that a determination of the total plant food contained in the soil, or a partial analysis of the soil by any one of the various methods that have been proposed by soil investigators does not give the exact information needed in respect to the immediate needs of the soil, for the three principal forms of plant food, namely, nitrogen, phosphoric acid and potash.

Taking these facts into consideration soil chemists have been compelled to go a step further in order to see if this information could be furnished. It has been found by experimentation that the soil waters and plant juices are acid, and that plant food is taken up in this weak acid menstrum. A duplication of this weak acid solution was resorted to. The amount of plant food taken up by the weak solvent proposed was thought to represent the available plant food of the soil. The determination of this so-called available plant food has been one of the greatest difficulties with which agricultural chemists have had to contend.

It has been found on analysis that most soils have phosphoric acid present in sufficient quantity to produce crops for many years, nevertheless when phosphoric acid is applied to soils in an available form, it, as a rule, gives increased yields to those crops which especially require this form of plant food for their growth. These applications of phosphoric acid, when evenly distributed through the soil are often so small that detection by chemical means is almost an impossibility.

It has been claimed by some that the phosphoric acid held by the soil is not available to the plant, while, on the other hand, that furnished from phosphatic material when applied to the soil was available. Whether this be true or not, it is a well known fact that as a general rule, applications of phosphoric acid exert a stimulating effect on the young plant's development, and for that reason it is said to be available and assimilated.

Chemists and soil investigators have made many attempts to devise methods for the estimation of the available plant food of the soil. Many solvents have been tried, each solvent having the power to dissolve out different amounts of plant food. When correlation of dissolved material with the amount taken from the soil by the plant, or with the yield was attempted, no definite relation could be obtained.

According to present day ideas, that portion of the phosphoric acid extracted from fertilizers, using water or a neutral ammonium citrate solution, is regarded as available plant food. These methods, though arbitrary, have given fairly satisfactory results. When this so-called available phosphoric acid is applied to soils it gives increased yields. By this form of phosphatic material is meant those forms of phosphate that have been treated with sulphuric acid, the product being known in the market as acid phosphate. Alkaline phosphates have also come into use in recent years, and experiments have proven them to be about as good as acid phosphate. Still the neutral ammonium citrate solution fails to dissolve the quantity of phosphoric acid from the alkaline phosphate, as from acid phosphate. This method therefore fails to show the true availability of the alkaline phosphates.

Many methods have been proposed for the estimation of the availability of the different phosphates. A two percent solution of citric acid was proposed by Wagner as a suitable solvent for the estimation of phosphate availability. This solvent has given very satisfactory results in the estimation of available phosphoric acid in such materials as basic slag and other phosphate compounds of an alkaline nature.

In subjecting a soil to a strong acid treatment, such as hydrochloric acid (sp. gr. 1. 115), we are able to arrive at some idea in regard to the crop producing power of the soil over long periods of time, but this method fails in that it does not give the amount of phosphoric acid in the soil that is available for the plant's growth and development.

Dr. Bernard Dyer[1] of the Rothamsted Experiment Station, England suggested a method for the determination of plant food availability based on the results he obtained on the analysis of the acid juices of over 100 varieties of plants. The average root acidity was found to be about 0.91 percent. Taking these results as a basis to work upon Dyer proposed his 1 percent citric acid solution for the estimation of available phosphoric acid. He claimed that by this method the available phosphoric acid of soils could be distinguished from the unavailable. Chemists of this country have studied this method very carefully, and have proposed many others in an effort to arrive at something definite in regard to the available phosphoric acid of the soil. The more successful of the recent methods proposed for the determination of the available plant food of the soil, seems to be the *Fifth Normal Nitric Acid Method*. It is claimed by some investigators that the amount of phosphoric acid dissolved from the soil by this solvent approaches the true available phosphoric acid held in the soil. This, it is said, is shown by crop yield on the soils studied.

[1]Jour. Chem. Soc. 1894, Trans. 141.

Hartwell[2] thinks that it is very doubtful if any solvent will take from the soil amounts of phosphoric acid showing a definite relation to the amounts of phosphoric acid removed by crops. This investigator said: "This is especially true when a large proportion of the total amount of this element is in combination with organic material and must depend upon the micro-organisms of the soil for its liberation."

Jordan[3] in a recent publication in which he gives the results of his experiments upon nine soils of different origin found that, "By no one of these methods of chemical examination was there established any relation between the amounts of nitrogen, phosphoric acid and potash, either total or soluble, and crop producing capacity." He did find that, "There appeared to be some relation between the total soluble matter in the soil and productiveness, to the extent that the two soils giving a very low yield of barley showed greatly less solubility than did the others. This relation, however, was not consistent throughout." He concluded by saying, "The general result of this investigation shows that we are not yet in a position through laboratory methods so far devised to measure the fertility of the soil." The soils studied by Jordan were subjected to chemical examination by the following methods: Complete analysis, hydrochloric acid, (sp. gr. 1.115), N 200 and N 25 hydrochloric acid and water.

In studying the amount of humus contained in the soil, some chemists have given special emphasis to the phosphoric acid that is dissolved with the humus when treated with the ammonia solution. Phosphorus in this condition has been called humic phosphate and it is believed by some investigators that the plant is capable of making use of large quantities of phosphorus from it. Phosphorus in this combination has been studied by Fraps[4] who says, "It appears probable that the mineral phosphates of the soil may give up some of their phosphoric acid to ammonia, and also that the inorganic phosphoric acid dissolved in the ammonia is probably of low agricultural value, being dissolved from iron and aluminum phosphates."

In a chemical study of a number of Wisconsin soils, Whitson and Stoddard[5] used 1 percent solutions of sodium and ammonium hydroxide. These solutions do not show the phosphoric acid existing in the soil in combination with calcium, but they take into solution those phosphates that exist in combination with iron, aluminum and humus. Fifth Normal Nitric Acid, according to Whitson and Stoddard is an accurate indicator of soil needs, as it determines the calcium phosphate and gives evidence as to the phosphate requirements of the soil.

[2]Proc. A. O. A. C., pp. 84-85. 1898.
[3]Bul. No. 426, N. Y. Exp. Sta. 1916.
[4]Jour. Am. Chem. Soc. Vol. XXXIV, No. 5.
[5]Research Bul. No. 2, Wis. Exp. Sta.

Effect of Fifth Normal Nitric Acid on Virginia Soil Types

It has been found after investigating numerous samples of soil derived from the different geological formations in the state, that they are very deficient in available phosphoric acid. Therefore, we would expect the soils of Virginia to respond to applications of phosphatic fertilizers. In many instances this has been found to be true. Taking all of these facts into consideration and realizing the importance of this question to the farmers of the state, the Department of Chemistry has been studying the availibility of several of the more important phosphate fertilizers, hoping that some information might be gained in order to answer the following questions:

1. What becomes of the phosphoric acid from fertilizers left in the soil, after the removal of the first crop?
2. Is this excess of phosphoric acid a deposit, from which the farmer draws interest, or is it lost by being changed into compounds, in the soil, unavailable to the plants?

The phosphates used in the experiments were:

Tetra-calcic (4-lime phosphate), a product of steel manufacture.
Tri-calcic phosphate (3-lime phosphate), mineral and bone phosphate.
Di-calcic (2-lime phosphate), reverted phosphoric acid.
Mono-calcic (1-lime phosphate), water soluble phosphoric acid.

Acid phosphate is the most common form of phosphatic material used in furnishing phosphorus to plants. As is well known, it is prepared by treating rock phosphate with sulphuric acid. The products of such treatment are mono- and di-calcic phosphates, which taken together compose what is known as the available phosphoric acid of acid phosphate. Monocalcic phosphate is soluble in water and when applied to the soil dissolves in the soil water and combines with certain compounds in the soil.

It has been known for some time that soluble phosphates are reverted or fixed. When the combination is with the iron and aluminum compounds of the soil, it may be that the combination is so strong that the fixation changes the solubility of the phosphate into forms remaining forever unavailable to the plant. If this be true it is needless to apply large quantities of soluble phosphate to soils, in which iron and aluminum compounds predominate over the other bases as four-fifths of it would be lost forever, and would remain as dead capital to the farmer.

The use of slowly available compounds such as floats, would be preferable, as the solubility of this material is such, that small quantities would be present in the soil at all times, available to the plant. The reversion in this case would be slow, hence it would be more economical to use such compounds rather than the more soluble forms of phosphoric acid. In in-

vestigating these questions laboratory, pot, cylinder, and field experiments were resorted to.

The Ability of Virginia Soils to Fix Phosphoric Acid

The report of 1909 and 1910[6] gave the laboratory and pot work done on the fixation of phosphoric acid by several of the leading Virginia soil types. It was found that soils of certain geological origin containing large quantities of iron and aluminum possess the greater fixing power, while those of recent geological origin fix the least. In one case the fixation was 95.1 percent, and in the other 17.1 percent.

If the phosphoric acid from a solution of acid phosphate retained in the soil after treating it with weak solvents, is a measure of its fixing power, and the compounds are unavailable to plants, then it can be clearly seen that it would be folly to apply large quantities of soluble phosphorus to soils similar to the Albemarle type, as nearly all would be lost.

Experiments in sand culture were made adding the phosphates in forms that had been fixed. Wheat was used as the first crop.

These experiments showed that if the yield is taken as a measure of the availability, iron and aluminum do not fix phosphoric acid in forms unavailable to the wheat plant. The second crop, which was oats, showed practically the same results as the wheat. In a third set of pot experiments corn was grown and similar results were obtained as with wheat and oats. Therefore, it seems that in pot experiments, the above plants can go even further than the results shown by Fifth Normal Nitric Acid extraction and make use of forms of phosphoric acid shown to be unavailable by this solvent.

CYLINDER EXPERIMENTS ON VIRGINIA SOIL TYPES

In order that the conditions of further experimentation on the fixation of phosphoric acid by Virginia soils might conform as near as possible to those in actual practice, cylinder experiments were resorted to.

The cylinders were made of galvanized iron 23½ inches in diameter and 4 feet deep. These were painted inside and out to retard corrosion. The sub-soil was obtained from Blacksburg and is what is known as the Hagerstown Loam. This sub-soil was filled to within 8 inches of the top of each cylinder. The cylinders were tile drained and the soils used were from Albemarle, Appomattox, and Norfolk counties. The first three types were of old geological origin and of high fixing power. The latter type was a Coastal Plain soil and of low fixing power.

Va. Exp. Sta. Repts. 1909-10.

TABLE I.—*Analysis of the Phosphates Used in the Experiments*

SALT	FIXING AGENT	TOTAL P_2O_5
		Percent
Mono-Calcic Phosphate	$Fe_2(OH)_6$	3.54
Acid Phosphate	$Fe_2(OH)_6$	2.59
Acid Phosphate	$Al_2(OH)_6$	2.33
Acid Phosphate	$CaCO_3$	3.70
Acid Phosphate		16.00
Virginia-Carolina Phosphate (di-phosphate) Citrate, insoluble, 5.068 Water, soluble... Trace Citrate, soluble..23.01		28.08
Floats		29.96

From the above data the phosphate carrying the smallest amount of total P_2O_5 was selected as a basis of calculation. This salt was found to be acid phosphate fixed by aluminum hydroxide yielding 2.33 percent P_2O_5 on analysis. The actual amount of P_2O_5 added to each cylinder was .2796 grams.

In a former paper[7] it was stated that where experiments were conducted with the solvents used to determine the availability of phosphoric acid in soils and fertilizers, it was proved that the different soil types fixed phosphoric acid from water solutions into compounds of different solubility.

The hydroxides of iron and aluminum lock up or fix 60 to 70 percent of the water soluble phosphates into insoluble, or, as measured by the solvents, into unavailable forms. Where lime was mixed with equal quantities of iron or aluminum hydroxides the fixation of phosphoric acid was not so great as 57 percent was available, showing that a part combined with lime. Where calcium and magnesium carbonates were used as fixing agents, the resulting compounds were completely dissolved and would be classed as available.

The soils in the cylinders were exhausted of phosphoric acid as much as possible before applying the fixed salts and other forms of phosphoric acid. The crops grown during this preliminary treatment were oats, sorghum and corn. After these crops were harvested, fertilizers were applied and the cylinders then sown the three succeeding years, to wheat, turnips and corn.

[7]Contribution to the Study of Phosphoric Acid in Soils and Fertilizers. Ellett and Hill. Va. Exp. Sta. Repts. 1909-10.

Crop Yields from Cylinders

Table II.—*Albemarle Soil (Fixing Power 95%)*

Fertilizer Applied	Wheat	Turnips	Corn
	Grams	*Grams*	*Grams*
Acid Phosphate	76	89	37.5
Acid Phosphate Fixed by $CaCO_3$	97	99	59.5
Acid Phosphate Fixed by $Fe_2(OH)_6$	105	65	61.5
Acid Phosphate Fixed by $Al_2(OH)_6$	104	102	70.3
Mono-Calcic Phosphate Fixed by $Fe_2(OH)_6$	77	79	85.0
Virginia-Carolina Phosphate	93	102	73.3
Floats	46	224	44.6
Nitrogen and Potash	52	118	26.5
Check	58	——	27.4

Table III.—*Appomattox Chocolate Soil (Fixing Power 89%)*

Fertilizer Applied	Wheat	Turnips*	Corn
	Grams	*Grams*	*Grams*
Acid Phosphate	81	339	148.9
Acid Phosphate Fixed by $CaCO_3$	55	183	111.5
Acid Phosphate Fixed by $Fe_2(OH)_6$	92	149	111.4
Acid Phosphate Fixed by $Al_2(OH)_6$	107	102	114.4
Mono-Calcic Phosphate Fixed by $Fe_2(OH)_6$	111	288	128.5
Virginia-Carolina Phosphate	145	198	130.4
Floats	95	102	44.6
Nitrogen and Potash	198	226	146.4
Check	175	115	110.5

*The stand obtained was uneven.

Table IV.—*Appomattox Light Soil (Fixing Power 58%)*

Fertilizer Applied	Wheat	Turnips	Corn
	Grams	*Grams*	*Grams*
Acid Phosphate	77	66	83.6
Acid Phosphate Fixed by $CaCO_3$	84	192	88.6
Acid Phosphate Fixed by $Fe_2(OH)_6$	55	124	96.2
Acid Phosphate Fixed by $Al_2(OH)_6$	44	105	69.4
Mono-Calcic Phosphate Fixed by $Fe_2(OH)_6$	167	126	98.6
Virginia-Carolina Phosphate	71	44	74.8
Floats	56	327	73.0
Nitrogen and Potash	72	419	108.5
Check	68	328	72.1

TABLE V.—*Norfolk Soil (Fixing Power 17%)*

FERTILIZER APPLIED	WHEAT	TURNIPS	CORN
	Grams	*Grams*	*Grams*
Acid Phosphate	220	648	200.7
Acid Phosphate Fixed by $CaCO_3$	203	272	180.5
Acid Phosphate Fixed by $Fe_2(OH)_6$	295	194	180.7
Acid Phosphate Fixed by $Al_2(OH)_6$	279	459	182.5
Mono-Calcic Phosphate Fixed by $Fe_2(OH)_6$	220	579	183.3
Virginia-Carolina Phosphate	170	376	165.3
Floats	123	335	132.3
Nitrogen and Potash	111	278	145.0
Check	75	388	111.7

The fixed salts of iron, aluminum and calcium produced larger yields of wheat when added to the Albemarle soil, than did the more soluble forms of phosphoric acid represented by acid phosphate. Floats when compared to the check cylinder gave about the same results. No special response was obtained by an addition of nitrogen and potash. Turnips appeared to have a greater drawing power upon the phosphoric acid of floats than any of the other crops grown on this soil type. Acid phosphate and the fixed forms of phosphoric acid gave about the same yields with this crop. In the case of corn, the phosphoric acid from the fixed salts gave larger yields than acid phosphate. Plant growth as a whole was not as good on this type of soil as on some of the others. Experience has shown this soil to be some what unsatisfactory for pot and cylinder work on account of its tendency to bake. This is probably one of the causes for the diminished yields.

With the Appomattox chocolate soil the first two crops failed to give any definite results, but with corn the cylinders to which the fixed salts had been added gave as good yields as the more soluble forms of phosphoric acid. With this soil type floats gave very small yields.

Appomattox light soil gave varying results with wheat and turnips, but with corn the fixed salts carrying phosphoric acid gave as good yields as acid phosphate. The plants grown on this type of soil showed an unusual ability to make use of mono-calcic phosphate fixed by iron hydroxide.

On the Norfolk soil all of the fixed salts with the exception of phosphoric acid fixed by calcium carbonate gave as good, if not better yields than acid phosphate, when wheat was used as an indicator. With turnips, acid phosphate gave the best returns. Acid phosphate gave larger yields with corn, but the cylinders to which the more insoluble forms of phosphate had been added, were almost as large.

It must be remembered in reviewing these results that it is difficult to draw any definite conclusion from the yields of only three crops, as the

only application of the fixed salts was made just before wheat was sown. The phosphoric acid remaining in the soil after harvesting the wheat might undergo some change and become less available, and the amount present would necessarily be diminished by the removal of each crop. This may explain in a way why the cylinders fertilized with nitrogen and potash and the check, gave increased yields with turnips and corn. This probably shows that the weathering agencies liberated sufficient phosphoric acid from the soil to give larger yields when turnips and corn were grown.

FIELD STUDIES ON THE FIXATION OF PHOSPHORIC ACID

In our study of the fixation of phosphoric acid by different prepared chemical substances and by the soil, it has been demonstrated that the Albemarle type of soil retained practically all of the phosphoric acid added to it. With soils of limestone derivation, over 50 percent of the phosphoric acid would be redissolved in Fifth Normal Nitric Acid. This amount would probably be available to the plant, if this solvent be considered as a measure of availability. The clay soil from Albemarle was practically free of lime and the assumption is made that the phosphoric acid in this soil exists as iron and aluminum phosphates. Pot experiments, as has been noted, show that Fifth Normal Nitric Acid is not a measure of the availability of phosphoric acid when locked up in the more insoluble forms, such as iron and aluminum phosphates, and no correlation of yield could be made on the basis of its solvent action. These results were obtained in the laboratory and green house. In order to determine whether these results represent in any way conditions in general farm practice, we have tried to verify them under field conditions.

Plan of Experiment

In drawing up plans for the field work, the feeding power of the different plants was considered. Corn was selected as the most suitable crop as soil samples could be taken throughout the growing season without injury to the crop. These experiments were begun in 1907 and the results recorded are from this year, through 1916, or results on nine crops of corn. No results are recorded for 1914 on account of drouth.

Soil samples taken from the plats were analyzed monthly during the growing season. Fifth Normal Nitric Acid was used to study the changes that might take place in the composition of the soil, when large or small amounts of plant food were applied, so as to correlate, if possible, the amount of available plant food as measured by this solvent, with the crop yield.

It is thought by some that Fifth Normal Nitric Acid differentiates phosphates when in combination with different substances, especially the combinations of phosphorus and calcium from those of iron and aluminum. This has been shown by the investigations of Fraps, Whitson and Stoddard as well as by our own studies. Fraps[8] states, "The phosphoric acid dissolved from soils in excess of nine parts per million is, in most cases, present as phosphate of lime." This conclusion is based on the results of pot experiments.

Description of Soil Used in Experiments

The type of soil used in these experiments is what is known as the Hagerstown series, according to the Bureau of Soils' classification. These soils are considered very productive, and are loams and clay loams containing cherty material of different sizes. The soil used was light gray and ranged in depth from 6 to 10 inches, being underlain by a reddish yellow clay sub-soil. All of these soils are derived from the Shenandoah limestone which outcrops in this field.

The cropping history of this particular soil is not definitely known, but it has probably been under cultivation for not less than 75 years. This is perhaps the reason why the chemical analysis of this soil shows it to be low in phosphoric acid, nitrogen and potash, as little if any fertilizing material, either mineral fertilizer or manures, have been added.

TABLE VI.—*Analysis of Soil from the Experimental Plats (Surface Soil)*

	Percent
Insoluble matter (in hydrochloric acid sp. gr. 1.115)	89.56
Potash	.16
Soda	.09
Lime	.76
Magnesia	.71
Iron oxide	.87
Alumina	1.47
Phosphoric acid	.07
Sulphuric acid	.03
Water and organic matter	4.36
Humus	.81
Nitrogen	.136
Total potash (Smith fusion)	.200
Total phosphoric acid (Sodium per-oxide fusion)	.133
Available potash by Fifth Normal Nitric Acid	.02037
Available phosphoric acid by Fifth Normal Nitric Acid	.004071

Before beginning the experiment, samples of soil were taken from each plat, thoroughly mixed and a sample from this composite

[8]Bul. 126. Texas Exp. Sta., p. 39. 1909.

taken for analysis. The analysis of the composite sample showed a phosphoric acid content of .133 percent, which would probably be an adequate amount. On analysis with hydrochloric acid (sp. gr. 1.115) .07 percent phosphoric acid was found, which indicates that this soil type is deficient in this form of plant food. When the soil was subjected to analysis with Fifth Normal Nitric Acid only 40 parts per million were present. This also shows a deficiency.

Fraps[9] in his investigations on the availability of phosphoric acid as measured by the solvent power of Fifth Normal Nitric Acid assumes that a soil containing 30 to 100 parts per million phosphoric acid has an average possibility of 19.7 to 26.3 bushels of corn per acre. Samples of soil taken from the check plats on analysis gave 26.02 parts per million available phosphoric acid, and a yield of 42.32 bushels of corn. The figures of Fraps are somewhat low on yield, but it is fair to state that this investigator's figures are based on pot experimentation. The phosphoric acid available as shown by extracting with Fifth Normal Nitric Acid, was not adequate for the production of 42.32 bushels of corn per acre. When the nitrogen and humus of these plats was determined sufficient amounts were present to produce a yield as great as this. This leads us to believe that the corn plant fed partially upon the organic forms of phosphorus contained in the humus.

The following amounts of nitrogen and humus were found on analyzing the soils by the A. O. A. C. methods for these substances.

TABLE VII.—*Amounts of Nitrogen and Humus in the Plats*

Plat No.	Nitrogen	Humus	Plat No.	Nitrogen	Humus
	Percent			*Percent*	
1	.136	1.31	14	.112	1.29
2	.118	1.25	15	.110	1.25
3	.116	1.27	16	.106	1.20
4	.116	1.29	17	.114	1.27
5	.102	.97	18	.105	1.10
6	.102	1.01	19	.105	1.16
7	.100	1.10	20	.103	1.05
8	.095	1.01	21	.098	1.07
9	.104	1.06	22	.094	1.08
10	.097	1.06	23	.108	1.05
11	.101	1.10	24	.106	1.12
12	.110	1.22	25	.093	1.00
13	.115	1.21	26	.103	1.18

[9]Bul. 126. Texas Exp. Sta., p. 72. 1909.

Arrangement of Plats

Twenty-seven 1/30 acre plats which had been uncultivated for a number of years were used for these investigations. The plats were located on what is known as the Hagerstown area, the soil type being the Hagerstown loam. All of the plats were of approximately the same shape. A roadway 13.9 feet separated the series, with walkways 3 feet wide between the plats, so that in cultivating, the fertilizer from one plat would not be carried over to one of different treatment. The cultivation given to the plats was the same in all cases. The corn was harvested and the land allowed to remain bare until the following spring, when it was plowed again and planted to corn. This treatment was followed for the first five years of the experiment. At the beginning of the sixth year (1912) clover was sown on all the plats at the last working of corn, with the view of increasing the store of nitrogen and organic matter of the soil. The clover was turned under between the first and fifteenth of May and the fertilizers applied. The growth of clover has been poor on all plats except those receiving stable manure and complete fertilizer.

The fertilizer treatment of plats is shown in Table VIII.

TABLE VIII.—*Fertilizer Treatment of Plats*

Plat No.	Tons	Lbs.	Fertilizer Applied	Pounds Plant Food Per Acre
1		600	Acid Phosphate	103 P_2O_5
2		200	Acid Phosphate	34 P_2O_5
3		99.6	Floats	34 P_2O_5
4		99.6	Floats	34 P_2O_5
5		192	Thomas Slag	34 P_2O_5
6		192	Thomas Slag	34 P_2O_5
7		400	Acid Phosphate	58.5 P_2O_5
8		100	Nitrate Soda	15.7 N
		200	Acid Phosphate	34.0 P_2O_5
9		100	Nitrate Soda	15.7 N
		50	Sulphate Potash	25.0 K_2O
10		100	Nitrate Soda	15.7 N
		100	Sulphate Potash	25.0 K_2O
11			Check	
12			Check	
13			Check	
14			Check	
15	10		Stable Manure	66.6 P_2O_5 100.0 N 100.0 K_2O
16	10		Stable Manure	
17	10		Stable Manure	66.6 P_2O_5 100.0 N 100.0 K_2O
		1,200	Lime	
18		1,200	Lime	
19			Check	
20			Check	
21		100	Nitrate Soda	15.7 N
22		100	Nitrate Soda	15.7 N
23			Check	
24			Check	
25		100	Nitrate Soda	15.7 N
		50	Sulphate Potash	25.0 K_2O
		200	Acid Phosphate	34.0 P_2O_5
26		50	Sulphate Potash	25.0 K_2O
27			Allowed to remain in grass	

It will be seen from the foregoing plan of the experiment that plats 1 to 7 are treated with phosphates. The same number of pounds of phosphoric acid from acid phosphate, floats, and Thomas Slag are compared. In plats No. 7 and 1 two and three times as much phosphoric acid from acid phosphate was added, as was applied to the other plats. This was done to measure the increased amount of phosphoric acid soluble in the soil, as indicated by the Fifth Normal Nitric Acid method. The other plats were intended to show the effect of fertilizer and no-fertilizer treatments upon the available plant food in the soil.

Before planting the corn soil samples from each plat were taken and fertilizer applied. Each month during the growing season soil samples were taken from the plats, the phosphoric acid and potash determined, using Fifth Normal Nitric Acid as the solvent. The soil samples were taken the first of each month. However, this could not be strictly adhered to on account of rain.

The phosphoric acid and potash results are expressed in parts per million. This method was adopted for the reason that when the plats are compared on the percentage basis the results are entirely too small to give a comparative idea.

Soil samples were never taken from the plats until the soil was sufficiently dry to cultivate. The samples when taken contained about 15 percent moisture. If the preceding month had been dry the soil contained more phosphoric acid than if it had been wet. Such a condition may be noticed from the phosphoric acid determinations made in 1910. The amount present during this whole period was relatively higher than for the preceding years, while the crop yields were much lower. These results go to show that the phosphoric acid was carried down to depths greater than seven inches, and by the process of evaporation, concentrated in the upper layers of the soil.

At the end of the five-year period (1911) total phosphoric acid determinations by the per-oxide fusion method, failed to show any great difference in the percentage composition of the soils for phosphorus over the original analysis made in 1907 before fertilizers were applied, notwithstanding the fact that large quantities of phosphoric acid had been applied to a number of the plats.

When 600 pounds of acid phosphate per acre are added to a soil, as was the case with plat No. 1, there is added to the soil 103 pounds P_2O_5. When we take the weight of the first seven inches of soil at 2,000,000 pounds, the phosphoric acid content of the soil is increased 51.5 parts per million. The analysis of the original sample from plat No. 1, gave 40.7 parts per million P_2O_5, and a sample taken one month later gave 95.9 parts per million. When we take into consideration the amount added and that found, an in-

crease of only 3.7 parts per million is shown. This small difference is within the limit of analytical error. These figures go to show that acid phosphate when applied to this type of soil, is not fixed in an insoluble form. The results lead us to believe that the combination in this soil type is between the phosphoric acid and lime, rather than iron and aluminum, and therefore, Fifth Normal Nitric Acid will recover the phosphoric acid of the soil when in combination with lime. Over a period of five years it was found that the availability of Acid Phosphate was not diminished This was also found to be true when phosphorus in other combinations was applied.

At the last sampling in September (1907), four months after applying the fertilizer, 74.2 parts per million P_2O_5 were recovered by the Fifth Normal Nitric Acid method of extraction. This goes to show that 18 parts per million P_2O_5 had been changed into an insoluble condition in the soil. or had been made use of by the corn plant.

The check plats (Nos. 11, 12, 13 and 14), before planting gave 24 parts per million P_2O_5. At the last analysis of the sample taken from these plats in September, 14.4 parts per million were found. The crop, therefore, removed 9.6 parts per million P_2O_5 as the yields in 1907 were approximately the same.

Plats Nos. 2, 3, 4, 5 and 6 received 200 lbs. of acid phosphate or its equivalent. The value of this amount of phosphoric acid when expressed as P_2O_5 would be about 17.1 parts per million. Its effect is evident, as extraction with Fifth Normal Nitric Acid shows an increase the following year when the samples taken before fertilizers were applied were analyzed. These increases in phosphoric acid are especially noticeable during the years 1910 and 1911. The plats which received no fertilizer all show a decrease in phosphoric acid soluble in Fifth Normal Nitric Acid.

According to the amounts of P_2O_5 soluble in Fifth Normal Nitric Acid from floats and Thomas Slag, it appears that the phosphoric acid of these substances is available to the plant. This phosphorus, however, is not in a water soluble form. Its combinations would be more stable than acid phosphate, with less tendency to change into more insoluble forms with iron and aluminum. This fact is demonstrated when plats Nos. 2, 3, 4, 5 and 6 are compared. These plats received 200 lbs. acid phosphate, floats and Thomas Slag, respectively. Plats 3 and 4 and 5 and 6 being duplicates. When the analyses of these plats are compared it will be seen that about three times the quantity of phosphoric acid was soluble in the May samples of 1911, than was found in the May samples of 1907, on the floats and Thomas Slag plats. These conclusions are from the study of the results of the first five-year period.

In studying the results of the first five years we found that on plat No. 1 which received an application of 600 lbs. of acid phosphate, that the difference in phosphoric acid soluble in 1907 and in 1911 was 47.23 parts per million. Referring to the records given on page 61, it will be found that the phosphoric acid left in the soil and soluble in Fifth Normal Nitric Acid continued to increase, that is, when the soils were analyzed in May of each year. We have used this month because it represents the amounts of phosphoric acid left in the soil after the crop had been harvested. These samples were used also because of the length of time intervening, the fertilizers being able to adjust themselves to the new conditions.

When we study plat No. 1 in a critical way it can be seen that from 1907 to 1911 the phosphoric acid extracted with Fifth Normal Nitric Acid has been increased with each annual application of the acid phosphate, therefore, the reserve supply of phosphoric acid is being built up and it is reasonable to suppose that this reserve supply of phosphorus will continue to increase from year to year.

Table IX.—*Phosphoric Acid Recovered from Plats by Fifth Normal Nitric Acid**

Plat	Fertilizers Applied	1907 May	1907 June	1907 Sep.	1908 May	1908 June	1908 Aug.	1909 May	1909 June	1909 Aug.	1910 May	1910 June	1910 July	1910 Aug.	1911 May	1911 June	1911 July	1911 Aug.	Average Yield for Five Years Grain Bu.
1	600 Lbs. Acid Phosphate	40.7	95.9	74.2	54.4	92.9	85.0	64.9	123.6	157.5	89.31	91.14	174.96	57.71	87.93	265.64	227.25	183.5	40.51
2	200 Lbs. Acid Phosphate	33.0	52.9	49.5	44.1	42.1	49.1	45.8	36.1	43.5	56.33	89.77	69.62	87.09	41.68	88.85	77.86	83.5	39.43
3	99.6 Lbs. Floats	38.1	77.9	64.5	55.7	67.3	57.9	62.2	52.2	50.8	81.06	81.07	75.57	82.88	68.24	92.52	59.54	117.5	39.00
4	99.6 Lbs. Floats	33.0	55.2	51.3	37.9	40.3	52.3	54.1	61.8	60.9	60.91	77.86	74.19	52.21	59.08	90.68	85.19	72.5	39.59
5	192 Lbs. Thomas Slag	25.6	46.2	48.2	27.3	49.0	46.7	37.4	43.9	34.8	43.51	69.62	51.75	38.47	41.68	56.33	64.58	50.0	35.24
6	192 Lbs. Thomas Slag	25.6	25.9	24.0	43.2	40.7	36.5	28.9	29.7	33.8	44.42	60.46	68.24	37.46	64.12	72.36	51.30	42.5	32.85
7	400 Lbs. Acid Phosphate	26.7	64.7	55.3	26.9	45.0	45.3	45.6	54.5	55.4	46.26	90.60	98.01	60.46	28.40	124.58	89.31	83.5	29.32
8	{ 100 Lbs. Nitrate Soda; 200 Lbs. Acid Phosphate	19.9	31.3	30.1	23.6	21.9	29.9	19.7	37.5	48.5	28.40	88.39	38.47	37.10	26.10	47.63	43.06	82.0	42.43
9	{ 200 Lbs. Acid Phosphate; 50 Lbs. Sulphate Potash	13.2	25.4	39.8	15.8	23.3	29.9	22.0	21.6	32.5	28.40	58.58	30.69	23.31	21.98	52.67	43.97	84.0	36.21
10	{ 100 Lbs. Nitrate Soda; 50 Lbs. Sulphate Potash	10.2	14.4	9.0	11.4	14.1	12.6	32.0	27.5	21.5	20.15	32.06	13.74	15.11	8.70	29.31	12.82	18.0	38.42
11	Check	9.5	9.4	8.4	10.1	14.1	13.9	32.0	28.0	14.1	36.64	44.43	11.91	19.69	10.07	15.57	16.08	16.0	33.00
12	Check	27.1	27.1	9.2	26.6	24.7	22.6	21.5	16.9	26.1	35.27	42.59	20.15	22.78	21.33	26.56	24.73	24.0	35.90
13	Check	25.5	38.0	19.2	33.5	41.6	21.7	27.3	32.0	22.9	37.10	44.88	25.65	33.89	27.94	28.85	25.77	34.5	35.67
14	Check	34.1	42.2	21.0	43.7	25.6	28.6	33.4	43.9	32.9	36.18	44.88	28.85	31.14	29.15	43.05	34.35	24.0	39.85
15	10 Tons Stable Manure	37.4	66.4	53.0	57.2	87.0	88.8	48.5	60.4	65.0	95.26	106.71	82.90	68.70	58.17	89.31	87.02	85.0	57.43
16	10 Tons Stable Manure	29.0	54.3	75.9	81.7	63.2	59.5	49.0	65.0	63.2	78.32	106.71	99.28	84.81	66.41	85.70	81.07	74.5	56.14
17	{ 10 Tons Stable Manure; 1200 Lbs. Lime	46.0	52.2	48.2	44.3	80.1	63.9	49.0	61.3	64.1	61.37	101.68	75.57	76.08	55.42	100.76	77.77	94.0	64.07
18	1200 Lbs. Lime	33.1	21.8	30.7	23.4	27.9	27.9	20.3	18.3	32.4	27.48	65.58	47.17	29.77	22.90	27.48	32.06	23.0	47.46
19	Check	34.3	29.5	30.1	38.6	37.0	31.3	28.1	31.6	27.4	36.64	44.88	40.76	35.72	28.85	27.48	33.14	22.0	39.21
20	Check	30.1	28.9	21.0	23.4	26.9	27.2	18.9	27.1	38.4	27.94	32.46	22.27	22.90	23.36	21.01	24.27	23.0	41.57
21	100 Lbs. Nitrate Soda	30.1	30.1	25.9	30.4	36.4	36.0	26.9	27.0	24.7	30.23	50.38	47.17	27.02	23.36	28.40	23.82	18.0	43.98
22	100 Lbs. Nitrate Soda	21.0	31.3	12.0	13.3	32.3	25.4	21.5	22.5	19.6	28.40	38.01	48.55	18.78	24.27	17.86	28.00	15.0	40.71
23	Check	32.5	28.3	15.0	18.3	25.5	25.9	22.1	30.2	17.8	18.32	42.59	51.30	18.78	27.02	23.82	20.61	21.5	44.59
24	Check	15.3	22.3	15.0	15.2	24.0	19.5	15.3	18.3	15.5	34.35	39.39	40.76	17.80	22.90	21.53	21.53	31.5	35.35
25	{ 100 Lbs. Nitrate Soda; 200 Lbs. Acid Phosphate; 50 Lbs. Sulphate Potash	15.6	35.0	30.1	31.0	46.7	64.6	37.1	39.3	33.4	62.31	71.69	71.91	53.33	27.02	72.82	61.37	48.5	50.35
26	50 Lbs. Sulphate Potash	21.0	14.4	23.0	22.8	33.1	21.0	36.4	38.4	22.4	32.23	43.97	46.72	25.65	22.90	28.85	29.77	20.5	47.57

*Results expressed in parts per million P_2O_5.

TABLE IXA.—*Showing Fertilizer Treatments and Presence of Phosphoric Acid in the Soil of the Different Plats before the Fertilizer Treatments Were Begun in 1907 and Again After Ten Years of Treatment in 1916*

PLAT NO.	TONS	LBS.	ANNUAL FERTILIZER TREATMENT (Acre Basis)	PARTS PER MILLION P_2O_5 PRESENT 1907	1916	INCREASE OR DECREASE*
1		600	Acid Phosphate	40.7	193.5	152.8
2		200	Acid Phosphate	33.0	97.0	64.0
3 and 4		99.6	Floats	35.5	99.5	64.0
5 and 6		192	Thomas Slag	25.6	78.5	52.9
7		400	Acid Phosphate	26.7	146.5	119.8
8		200 100	Acid Phosphate Nitrate of Soda	19.9	63.5	43.6
9		200 50 100	Acid Phosphate Sulphate of Potash Nitrate of Soda	13.2	42.0	28.8
10		50	Sulphate of Potash	10.2	14.5	4.3
11, 12, 13, 14, 19, 20, 23 and 24			Received no Fertilizer	26.0	24.8	-1.2
15 and 16	10		Stable Manure	33.2	138.2	105.0
17	10	1,200	Stable Manure Lime	46.0	117.0	71.0
18		1,200	Lime	33.1	31.0	-2.1
21 and 22		100	Nitrate of Soda	25.5	23.0	-2.5
25		100 200 50	Nitrate of Soda Acid Phosphate Sulphate of Potash	15.6	57.0	41.4
26		50	Sulphate of Potash	21.0	39.0	18.0

*Decrease is indicated by the minus sign.

TABLE X.—*Showing the Disposition of P_2O_5*
(Results expressed in parts per million)

PLAT NO.	AMOUNT ADDED IN TEN YEARS	ORIGINALLY PRESENT	TOTAL	AMOUNT EXTRACTED IN MAY, 1916	AMOUNT TAKEN UP BY THE CROP OR FIXED
1	515	40.7	555.7	193.5	362.2
2	171.7	33.0	204.7	97.0	107.7
3 and 4	171.7	35.5	207.2	99.5	107.7
5 and 6	171.7	25.6	197.3	78.5	118.8
7	343.4	26.7	370.1	146.5	223.6

The acid phosphate used in these experiments carried 17.1 percent P_2O_5, equivalent to 103 pounds when applied at the rate of 600 pounds per acre. The equivalent of this amount of P_2O_5 would be 51.5 parts per

million, which would be distributed through the first acre seven inches of soil which weighs approximately 2,000,000 pounds.

This amount (51.5 parts per million) multiplied by ten or the number of applications, and adding the amount found on the original analysis, would give the total amount present in the soil, as represented by Fifth Normal Nitric Acid.

This takes into consideration only that amount applied in the form of various phosphates and that originally in the soil soluble in the solvent used. These calculations are shown in Table X.

Take for instance, plat No. 1 receiving an annual application of 600 pounds of acid phosphate per acre. The total amount added in ten years would be equivalent to 515 parts per million P_2O_5. There was originally present in this plat 40.7 parts per million P_2O_5 soluble in Fifth Normal Nitric Acid. These two amounts added together give a total of 555.7 parts per million.

On extracting the soil from this plat in May, 1916, before the annual application of fertilizers, with Fifth Normal Nitric Acid, an increase from 40.7 parts per million to 193.5 parts per million, was shown. The difference in the total and that amount extracted in May 1916, was 362.2 parts per million. This amount of P_2O_5 was either made use of by the corn plant or fixed by the soil.

Referring to Table X it will be seen that plat No. 2 receiving an annual application of 200 pounds of acid phosphate per acre, gave 107.7 parts per million P_2O_5 as the amount taken up by the plant or fixed by the soil. Plats Nos. 3 and 4 receiving floats equivalent to 200 pounds of acid phosphate gave the same results. Plats Nos. 5 and 6 receiving Thomas Slag at the same rate as the acid phosphate gave 118.8 parts per million taken up by the plant or fixed by the soil. This slight increase over the above plats is so slight that the general interpretation of the results from the application of the different phosphates is not materially changed.

It would be reasonable to assume that in taking one-third of the amount of phosphoric acid taken up by the crop, or fixed by the soil, that we would get figures approximating the amount fixed where applications of 200 pounds of acid phosphate were used. The amount found by this calculation was 120.8 parts per million P_2O_5, which is slightly above the anticipated result. This fact is also shown on plat No. 7, receiving an annual application of 400 pounds of acid phosphate per acre.

These results show for this soil type that relatively the same amounts of P_2O_5 are taken up by the plant or fixed by the soil, regardless of whether the phosphoric acid is applied to the soil in the form of acid phosphate, floats, or Thomas Slag. This interpretation is borne out by the average yields for nine years.

TABLE XI.—*Phosphoric Acid Recovered from Plats by Fifth Normal Nitric Acid**

Plat	Fertilizers Applied	1912 May	1912 June	1912 July	1912 Aug.	1913 May	1913 June	1913 July	1913 Aug.	1914 May	1914 June	1914 July	1914 Aug.	1915 May	1915 June	1915 July	1915 Aug.	1916 May	1916 June	1916 July	1916 Aug.	Av. Yield of Corn for 9 Yrs. in Bushels.
1	600 lbs. Acid Phosphate	152.5	213	174	114	112	251	209.5	235.5	71.5	260	132.5	253.5	227.69	379.5	361	359.5	193.5	217	197.5	234.5	39.00
2	200 lbs. Acid Phosphate	57	86.5	89.5	98	53	145	88.5	83	151.0	98	146	109	94.59	136.5	113.5	129.5	97	75.5	119.5	127.5	38.34
3	99.6 lbs. Floats	83	106.5	127	109.5	49	134	132.5	93.5	87.5	174.5	161.5	110	115.48	107	103	128	119	89.5	117.5	186.5	37.46
4	99.6 lbs. Floats	62	94	116.5	92.5	48.5	132	127.5	94.5	91.5	114.5	109.5	107	102.84	114	112.5	130	80	90.5	116	113	36.00
5	192 lbs. Thomas Slag	40.5	99.5	71.5	58	68.5	102.5	80	61	85	103.5	102	71.5	81.94	88	85.5	74.5	67.5	65.5	94	111.5	32.18
6	192 lbs. Thomas Slag	35.5	76.5	63	73.5	65	100.5	83	84.5	83	103.5	107.5	79.5	65.44	76	80	63.5	89.5	66	71	59	28.67
7	400 lbs. Acid Phosphate	62	94	139.5	117	120.5	137.5	139	119	94	130	173.5	131	118.23	162	142.5	174.5	146.5	264.5	147	115	26.86
8	100 lbs. Nitrate Soda 200 lbs. Acid Phosphate	29	77.5	49.5	51.5	57	70	68	52.5	85.5	41.5	92.5	68.5	41.79	46	56	62.5	63.5	121.5	64	61.5	39.78
9	200 lbs. Acid Phosphate 50 lbs. Sulphate Potash	22	27	24.5	40	40	39	52.5	51.5	90	139.5	49	45	34.09	70	39.5	45	42	49.5	61	64	35.08
10	100 lbs. Nitrate Soda 50 lbs. Sulphate Potash	11	10.5	17.5	13	28.5	17.5	76	40.5	42.5	17	25.5	39	17.59	15	17.5	14	14.5	17	21.5	10.5	30.50
11	Check	11	22	13	15	23	24.5	28	21	33	19.5	24	21.5	19.25	11.5	14	11	15.5	9	22.5	13.5	26.69
12	Check	19.5	31.5	25	27	45.5	30	44.5	29	39.5	28.5	25	30	17.59	30	22	15	17.5	16.5	22.5	21.5	27.14
13	Check	31.5	29	50	39.5	35	27	32	36	40	27	36	25.5	34.09	37	33	30	31.5	26	34	30.5	29.24
14	Check	25	27.5	28.5	31.5	26	76	40	40	22	40	28.5	86	35.74	25.5	26.5	29	38	37.5	36	30.5	36.38
15	10 tons Stable Manure	68	94.5	69	81.5	32	78.5	101.5	41.5	106.5	78	105.5	101.5	165.54	109.5	114	172.5	112	154.5	111	60	61.70
16	10 tons Stable Manure	64	134.5	126	87.5	41	53.5	101.5	183	86	144.5	121	139	156.74	129.5	114.5	118	164.5	151	123	50	59.59
17	10 tons Stable Manure 1,200 lbs. Lime	72	88.5	77	106	31.5	90.5	93	108	76	82	126	126	118	114	101	113	117	121	93	75	66.10
18	1,200 lbs Lime	25.5	27.5	20	18	40.5	29.5	46.5	36	12	37	30	28	26.94	24	26	17	31	29	30.5	17.5	51.26
19	Check	32	21.5	32	26.5	50	33.5	46	21	22	56.5	17.5	33.5	28.04	29	33	29	26.5	30.5	35.5	26.5	36.72
20	Check	23	26.5	29.5	21.5	20	41.5	42	42.5	16.5	28.5	28.5	27	24.47	20.5	18	17.5	29.5	29	24	27.5	37.66
21	100 lbs. Nitrate Soda	27.5	27	24.5	16.5	50	34.5	26	40.5	14.5	32	21.5	21	25.02	23.5	20	14.5	25.5	24.5	22.5	23	41.41
22	100 lbs. Nitrate Soda	21.5	34	25.5	14	45	28	34.5	41.5	10.5	26	21	20.5	23.09	16	16.5	12.5	20.5	18.5	31.5	13	37.36
23	Check	24	39	30	12	29.5	34.5	39	40	16.5	30	27	47.5	25.02	18	19.5	14	22.5	17	23.5	29.5	36.08
24	Check	29	28.5	36	15	49	27.5	35.5	36	14	29	20	55.5	18.69	15.5	16.5	15.5	18	12.5	19.5	33	27.81
25	100 lbs. Nitrate Soda 200 lbs. Acid Phosphate 50 lbs. Sulphate Potash	57.5	96.5	46	97	36	88	76.5	89.5	57	76	71.5	127	70.39	84	76	77.5	57	128	62.5	77.5	52.56
26	†50 lbs. Sulphate Potash	28.5	43.5	59	59	39	37.5	29.5	44	34.5	57	32.5	32.5	36.40	40	39	48.5	59	26	35.5	27.5	47.96

*Results expressed in parts per million.
†Dust from road influences the yield on this plat.

TABLE XII.—*Potash Recovered from Plats by Fifth Normal Nitric Acid**

Plat	Fertilizers Applied	1907 May	1907 June	1907 Sep.	1908 May	1908 June	1908 Aug.	1909 May	1909 June	1909 Aug.	1910 May	1910 June	1910 July	1910 Aug.	1911 May	1911 June	1911 July	1911 Aug.	Average Yield for Five Years Grain Bu.
1	600 Lbs. Acid Phosphate...	203.7	197.8	164.4	106.7	147.5	144.0	106.9	104.0	130.0	148.69	152.16	84.63	76.87	105.02	142.61	82.15	76.73	40.51
2	200 Lbs. Acid Phosphate. .	170.5	158.3	148.6	122.2	144.8	177.0	113.6	98.2	124.8	137.82	234.87	112.19	104.81	141.44	111.61	82.92	85.25	39.43
3	99.6 Lbs. Floats........	184.0	190.7	160.0	149.0	161.8	110.9	127.3	112.9	110.2	150.63	156.45	118.79	69.10	100.30	124.01	108.50	97.66	39.00
4	99.6 Lbs. Floats........	188.3	188.4	135.6	132.7	140.5	128.1	110.8	131.6	104.0	122.68	125.00	124.23	89.68	96.10	141.83	114.70	93.39	39.59
5	192 Lbs. Thomas Slag.....	142.4	156.6	156.2	96.2	93.9	87.3	110.0	83.8	77.6	126.56	107.93	100.55	65.99	103.86	91.07	65.87	64.71	35.24
6	192 Lbs. Thomas Slag.....	149.2	144.8	123.3	121.5	107.5	93.0	99.4	101.7	70.0	171.21	131.22	108.51	86.71	134.08	98.43	81.37	75.18	32.35
7	400 Lbs. Acid Phosphate...	162.2	230.1	123.3	116.8	78.8	84.1	112.9	100.5	89.0	126.95	87.35	104.43	65.97	58.52	91.84	87 19	82.92	29.32
8	{ 100 Lbs. Nitrate Soda.... { 200 Lbs. Acid Phosphate.	136.5	153.1	155.0	123.4	105.5	83.1	109.8	90.0	72.9	128.39	101.71	99.38	77.60	138.73	84.09	73.24	67.87	42.43
9	{ 200 Lbs. Acid Phosphate. { 50 Lbs. Sulphate Potash.	164.1	158.2	176.8	159.5	131.2	131.8	188.2	120.3	114.5	105.98	174.70	135.81	100.16	242.98	95 14	120.13	111 99	36.21
10	{ 100 Lbs. Nitrate Soda.... { 50 Lbs. Sulphate Potash.	179.0	141.8	137.7	138.9	92.3	155.2	135.9	141.3	141.7	122.68	225.56	74.15	92.78	239.49	140.28	83.31	82.54	38.42
11	Check	127.4	114.9	123.3	50.0	90.8	97.4	134.3	146.7	93.5	158.78	121.86	84.24	67.94	152.68	113.35	90.76	84.86	33.00
12	Check	185.0	137.7	143.1	128.1	167.7	141.9	165.7	162.4	103.6	199.16	149.27	49.30	108.70	123.62	113.74	101.14	97.60	35.99
13	Check	139.7	182.5	123.3	69.8	166.9	122.3	137.6	139.8	122.6	223.23	163.85	155.95	88.13	156.95	100.39	123.23	117.80	35.67
14	Check	158.2	176.7	123.3	91.2	113.7	139.5	151.4	146.3	124.6	127.34	196.42	98.04	60.56	149.58	108.89	125.94	116.64	39.85
15	10 Tons Stable Manure.....	156.2	328.8	254.8	191.3	317.1	291.4	344.9	348.6	192.5	213.91	286.12	98.06	61.73	305.37	168.18	313.89	312.72	57.43
16	10 Tons Stable Manure.....	168.5	254.0	460.4	212.7	313.6	263.2	255.6	262.1	235.2	206.92	348.23	288.80	59.40	223.21	458.44	286.76	278.24	56.14
17	{ 10 Tons Stable Manure.. { 1200 Lbs. Lime...........	164.4	217.6	288.2	163.2	308.2	237.1	310.7	316.0	226.7	223.23	325.18	256.61	51.63	180.58	353.03	320.09	317.76	64.07
18	1200 Lbs. Lime............	199.8	134.0	148.4	143.8	193.9	152.6	89.6	105.5	71.8	113.36	246.28	328.43	137.76	80.67	333.65	112.38	104.63	47.46
19	Check	168.7	166.9	121.7	121.5	185.4	151.7	84.2	135.9	93.1	118.41	135.86	158.00	122.28	96.88	120.52	75.56	71.69	39.21
20	Check	172.6	176.7	116.5	105.9	142.7	147.0	84.1	85.7	92.8	135.88	142.11	110.25	191.00	94.75	153.85	77.50	89.12	41.57
21	100 Lbs. Nitrate Soda......	137.7	166.1	136.5	112.5	142.3	128.3	86.8	127.3	77.6	188.67	193.46	166.15	168.49	111.99	103.47	101.53	102.30	43.93
22	100 Lbs. Nitrate Soda......	150.4	163.1	158.7	101.2	147.6	138.4	81.4	115.3	80.7	113.75	118.64	117.24	114.91	75.18	149.58	83.31	82.15	40.71
23	Check	179.6	193.2	174.7	184.9	144.0	168.2	85.2	94.2	88.1	144.42	149.86	141.31	197.22	101.53	129.04	93.00	91.84	44.59
24	Check	185.0	193.2	132.3	153.7	146.0	143.1	97.4	103.2	107.5	251.36	236.64	201.09	253.12	62.00	148.42	112.38	111.99	35.35
25	{ 100 Lbs. Nitrate Soda.... { 200 Lbs. Acid Phosphate. { 50 Lbs. Sulphate Potash.	123.3	172.2	127.3	137.4	146.0	160.5	73.4	75.2	134.7	92.86	106.31	153.34	154.12	101.53	187.95	113.93	110.83	50.35
26	50 Lbs. Sulphate Potash...	84.2	82.2	111.0	104.8	132.0	114.8	81.2	98.9	116.4	99.64	114.76	45.03	142.09	82.29	157.33	110.44	105.79	47.57

*Results expressed in parts per million K_2O.

The results on potash fluctuate to such an extent that we are led to believe that the amount of potash in the upper layers of the soil is constantly changing, due to effects brought about by rainfall and drouth, that portion of the potassium of the soil soluble in Fifth Normal Nitric Acid being constantly shifted from the upper to the lower layers of the soil and *vice versa*, while with the phosphoric acid we have found that the greatest amount soluble in Fifth Normal Nitric Acid, is found in the first six inches of the soil.

TABLE XIII.—*Potash Recovered fr*

Plat	Fertilizers Applied	1912 May	1912 June	1912 July	1912 Aug.	1913 May	1913 June	1913 July
1	600 lbs. Acid Phosphate	136.02	90.29	106.57	119.35	128.11	83.85	114.52
14	Check	90.06	155.39	90.35	99.98	146.75	60.95	126.17
15	10 tons Stable Manure	149.58	260.03	145.70	194.93	119.57	170.82	259.33
17	10 tons Stable Manure 1,200 lbs Lime	184.46	246.07	145.70	182.91	116.47	242.64	229.05
18	1,200 lbs. Lime	65.88	227.09	56.64	97.66	118.41	100.94	116.47
19	Check	89.13	97.27	89.90	93.82	184.40	56.29	89.29
25	100 lbs. Nitrate Soda 200 lbs. Acid Phosphate 50 lbs. Sulphate Potash	63.39	165.86	92.23	103.47	249.94	106.76	155.29
26	50 lbs. Sulphate Potash	91.07	120.91	82.93	90.29	159.17	123.07	137.04

*Results expressed in parts per million K_2O.

*Plats by Fifth Normal Nitric Acid**

1914				1915				1916				Av. Yield of Corn for 9 Yrs. in Bushels.
MAY	JUNE	JULY	AUG.	MAY	JUNE	JULY	AUG.	MAY	JUNE	JULY	AUG.	
102.10	111.42	112.97	90.84	137.50	103.65	189.85	104.82	116.07	183.24	139.76	100.94	39.00
82.69	145.97	123.06	104.82	170.81	93.94	110.64	80.16	201.87	367.64	179.36	109.48	36.38
191.39	177.80	411.51	322.22	134.94	310.09	295.04	421.99	266.70	178.86	487.99	274.08	61.70
95.12	178.19	419.39	364.92	295.26	337.75	283.40	278.35	385.50	161.88	380.46	269.04	66.10
93.17	111.81	114.52	81.14	91.48	108.70	113.38	107.15	546.61	195.66	136.27	126.17	51.28
107.54	81.91	116.46	114.52	106.75	92.00	110.64	203.82	81.91	358.33	137.04	121.51	36.72
107.52	165.22	100.55	112.98	164.18	217.40	151.40	230.99	161.99	331.54	131.99	138.98	52.56
100.16	144.81	137.82	123.84	138.78	197.21	178.82	108.70	76.48	90.46	150.63	139.76	47.96

TABLE XIV.—*Plat Experiments with Corn Showing the Effects of Fertilizers*

Plat	Fertilizers Applied	1907 Yield per Acre Grain Bu.	1907 Yield per Acre Fodder Tons	1908 Yield per Acre Grain Bu.	1908 Yield per Acre Fodder Tons	1909 Yield per Acre Grain Bu.	1909 Yield per Acre Fodder Tons	1910 Yield per Acre Grain Bu.	1910 Yield per Acre Fodder Tons	1911 Yield per Acre Grain Bu.	1911 Yield per Acre Fodder Tons	Average for 5 Years Grain Bu.
1	600 Lbs. Acid Phosphate	46.61	1.80	45.00	2.10	42.95	1.50	37.50	1.56	30.53	1.72	40.51
2	200 Lbs. Acid Phosphate	41.79	1.50	48.21	1.95	41.79	1.50	30.53	1.49	34.82	1.42	39.43
3	99.6 Lbs. Floats	46.61	1.95	46.61	2.10	39.64	1.65	25.71	1.36	36.43	1.60	39.00
4	99.6 Lbs. Floats	43.93	1.95	53.35	2.25	39.11	1.59	27.32	1.43	34.28	1.50	39.50
5	192 Lbs. Thomas Slag	41.79	1.80	44.46	1.95	39.11	1.29	19.28	1.56	31.60	1.20	35.24
6	192 Lbs. Thomas Slag	37.50	1.80	41.79	1.95	30.00	1.26	21.42	1.69	31.07	1.50	32.35
7	400 Lbs. Acid Phosphate	39.11	2.25	38.57	1.95	32.68	1.44	14.82	1.49	21.43	1.60	29.32
8	100 Lbs. Nitrate Soda 200 Lbs. Acid Phosphate	41.25	1.95	55.71	2.01	41.79	1.53	31.07	1.69	42.32	1.42	42.43
9	200 Lbs. Acid Phosphate 50 Lbs. Sulphate Potash	38.08	1.65	48.21	1.39	38.57	1.56	28.92	1.45	27.32	1.50	36.21
10	100 Lbs. Nitrate Soda 50 Lbs. Sulphate Potash	43.39	2.10	50.89	1.90	40.00	1.68	27.85	1.30	30.00	1.50	38.42
11	Check	43.93	1.95	40.18	1.72	36.96	1.50	24.64	1.23	19.29	1.05	33.00
12	Check	40.71	2.40	51.43	1.87	39.64	1.53	24.10	1.17	24.10	1.20	35.99
13	Check	42.86	1.80	45.00	1.51	36.43	1.35	24.10	1.30	30.00	1.50	35.67
14	Check	42.86	1.95	46.61	1.65	43.39	1.50	28.92	1.30	37.50	1.87	39.85
15	10 Tons Stable Manure	42.86	2.40	58.39	2.40	60.00	2.13	48.75	1.80	77.14	2.02	57.43
16	10 Tons Stable Manure	48.75	3.00	58.93	2.55	54.64	2.22	50.35	1.89	68.03	2.10	56.14
17	10 Tons Stable Manure 1200 Lbs. Lime	47.68	1.50	61.61	2.25	68.08	2.16	64.28	1.80	78.75	2.10	64.07
18	1200 Lbs. Lime	43.93	1.80	53.57	2.25	52.50	1.52	39.65	1.36	47.68	1.50	47.46
19	Check	44.46	1.50	47.14	2.17	39.64	1.50	30.00	1.17	34.82	1.80	39.21
20	Check	42.86	1.20	53.57	2.25	46.08	1.65	30.00	1.10	35.36	2.10	41.57
21	100 Lbs. Nitrate Soda	42.32	1.65	37.50	1.95	51.96	1.50	43.39	1.30	44.46	1.50	43.93
22	100 Lbs. Nitrate Soda	44.46	1.50	48.21	2.25	41.79	1.56	28.39	1.80	40.71	1.35	40.71
23	Check	40.71	1.80	62.14	2.85	38.08	1.59	15.00	1.23	37.50	1.05	44.59
24	Check	40.18	1.42	31.07	1.65	36.96	1.41	7.85*	.96*	33.21	1.20	35.35
25	100 Lbs. Nitrate Soda 200 Lbs. Acid Phosphate 50 Lbs. Sulphate Potash	44.46	1.65	60.00	2.55	64.28	2.07	40.17	1.95	42.86	1.87	50.35
26	50 Lbs. Sulphate Potash	55.71	1.80	42.86	1.80	58.93	1.95	33.21	1.88	47.14	2.04	47.57

*Not included in average

TABLE XV.—*Plat Experiments with Corn Showing the Effect of Fertilizers**

PLAT	FERTILIZERS APPLIED	1912	1913	1915	1916	AVERAGE YIELD OF CORN FOR 9 YEARS IN BUSHELS
1	600 lbs. Acid Phosphate	19.3	34.8	44.46	48.21	39.00
2	200 lbs. Acid Phosphate	27.3	32.1	39.91	49.82	38.34
3	99.6 lbs. Floats	27.9	34.8	33.21	46.07	37.46
4	99.6 lbs. Floats	27.3	30.5	32.14	40.71	36.00
5	192 lbs. Thomas Slag	18.2	22.5	33.21	42.59	32.18
6	192 lbs. Thomas Slag	12.3	21.9	33.21	32.95	28.67
7	400 lbs. Acid Phosphate	15.6	21.4	30.27	30.37	26.86
8	100 lbs. Nitrate Soda; 200 lbs. Acid Phosphate	27.3	34.8	39.91	46.54	39.78
9	200 lbs. Acid Phosphate; 50 lbs. Sulphate Potash	26.8	30.0	33.75	45.27	35.08
10	100 lbs. Nitrate Soda; 50 lbs. Sulphate Potash	15.0	25.1	17.14	33.11	30.50
11	Check	12.3	23.0	15.54	30.67	26.69
12	Check	12.3	18.8	14.46	27.59	27.14
13	Check	8.0	21.4	28.39	33.48	29.24
14	Check	27.9	30.0	32.50	41.25	36.38
15	10 tons Stable Manure	60.5	57.7	77.41	68.30	61.70
16	10 tons Stable Manure	60.5	55.7	71.43	64.55	59.59
17	10 tons Stable Manure; 1,200 lbs. Lime	63.2	60.0	79.02	70.31	66.10
18	1,200 lbs. Lime	53.6	51.5	52.50	62.81	51.28
19	Check	26.8	34.3	30.54	45.30	36.72
20	Check	24.6	35.3	34.29	40.81	37.66
21	100 lbs. Nitrate Soda	26.3	45.9	34.55	48.42	41.41
22	100 lbs. Nitrate Soda	24.1	34.8	29.19	47.28	37.36
23	Check	24.1	30.0	19.29	36.96	36.08
24	Check	21.4	12.4	14.46	32.81	27.81
25	100 lbs. Nitrate Soda; 200 lbs. Acid Phosphate; 50 lbs. Sulphate Potash	35.4	40.1	68.30	75.27	52.56
26	50 lbs. Sulphate Potash	48.4	40.7	42.86	61.07	47.96

*Yields for 1914 omitted on account of crop failure.

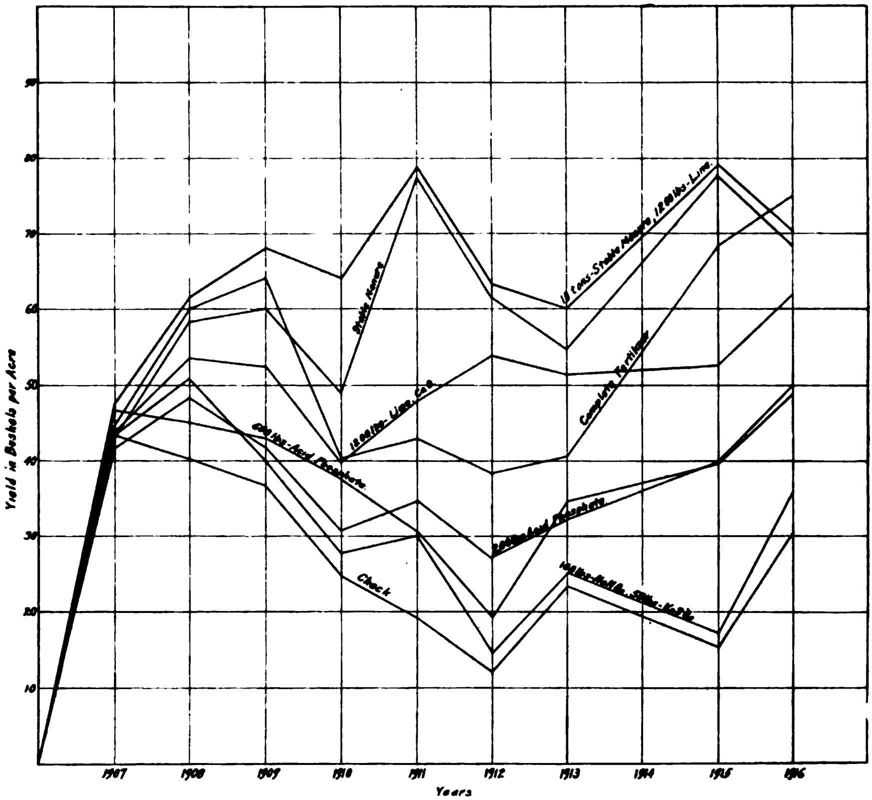


FIGURE 1.—*A graphic representation of yield of corn from plats receiving different fertilizer treatment for a period of nine years*

In a former report[10] covering the results obtained in the first five years of this work, it was shown that phosphoric acid and potash when applied to the soil, in the form of stable manure, could be detected by using Fifth Normal Nitric Acid as the solvent. The increase in parts per million of phosphoric acid for the first period of five years of this experiment on plats Nos. 15, 16, and 17, is doubled over that originally present in 1907. The check plats (Nos. 13 and 14) gave an average yield of 37.76 bushels of corn for the period. This yield did not decrease the amount of phosphoric acid as measured by the solvent used.

Additions of phosphoric acid and potash in the form of stable manure to plats Nos. 15 and 16, gave marked increases in yield. These plats gave an average yield of 59.21 bushels for five years.

[10] Va. Exp. Sta. Repts. pp. 116-182. 1911-12.

On plat No. 25 which received the complete fertilizer treatment, the phosphoric acid and potash remained about the same as was originally present in 1907.

The application of 1200 pounds of lime to plat No. 18 failed to affect the solubility of phosphoric acid and potash, although it gave slight gains over the plats receiving no fertilizer treatment.

On examining the results of the second five-year period it will be noticed that many changes not shown during the first period have taken place. The chart shows graphically the yields covering a period of nine years. The results shown are on the plats receiving stable manure, stable manure and lime, nitrate of soda and sulphate of potash, lime, acid phosphate at the rate of 600 pounds, acid phosphate at the rate of 200 pounds, complete fertilizer and check.

It appears from these results that 200 pounds of acid phosphate furnish sufficient phosphoric acid for maximum crop yield on this soil type. The yields were approximately the same as with an application of 600 pounds of acid phosphate. From the yields it appears that the crop drew upon the different carriers of phosphorus at about the same rate.

Plat No. 10 receiving nitrate of soda and sulphate of potash gave yields slightly above the check plats. This indicates that this soil type requires phosphorus in an available form rather than potash for increased crop production, as previous analyses of this soil have shown it to contain sufficient potash for maximum crop yields.

Plat No. 25 receiving 100 pounds of nitrate of soda, 50 pounds sulphate potash, and 200 pounds of acid phosphate, gave an average yield of 52.5 bushels of corn per acre, showing that these applications had maintained a high degree of fertility.

Stable manure applied at the rate of 10 tons annually, has shown a very beneficial effect on the crop yield over a period of nine years. The average yield was 60.65 bushels of corn per acre. The stable manure not only furnished nitrogen, phosphoric acid and potash in a readily available form, but this annual application has materially benefited the physical condition of the soil by the incorporation of organic matter.

With plat No. 18, receiving an annual application of lime at the rate of 1200 pounds per acre, no marked effect was shown for the first five-year period. Determinations of soil acidity over this period of time showed this plat to be acid. In 1912, plat No. 18 began to give increased yields. Acidity determination made in 1916 showed this plat to be alkaline. Samples were run to determine the exact time when this neutralization of the soil acids took place. This was found to be in 1912, the same year in which material increases were noticed. The application of 1200 pounds of lime showed no effect in the liberation of phosphoric acid, as measured by

Fifth Normal Nitric Acid. The beneficial effect of lime on this plat must be due to an increased liberation of available phosphoric acid and potash, which was not shown by extracting the soil with Fifth Normal Nitric Acid.

SUMMARY AND CONCLUSIONS

1. It has been found on investigating numerous samples of soil derived from the different geological formations of the state that Virginia soils are deficient in available phosphoric acid. Experiments have shown these soils to respond to available phosphatic fertilizers.
2. Certain soil types containing large quantities of iron and alumina possess the power of retaining or fixing the phosphoric acid when applied in soluble forms. This fixation is as great in some soils as 95 percent. The soils of the older geological formations possess the greatest fixing power, while those of more recent origin fix the least. The latter type has a fixing value of about 17 percent.
3. In cylinder experiments where the soils were fertilized with salts prepared in the laboratory, Fifth Normal Nitric Acid failed to show the true availability of these salts as compared with the crop yields.
4. When the soils from the plats were extracted with Fifth Normal Nitric Acid over a period of ten years it was found that the P_2O_5 increased with each annual application of phosphate from the three sources. Therefore the reserve supply of P_2O_5 is being built up and it is reasonable to suppose that this reserve supply will continue to increase from year to year
5. It is shown that on soils of the Hagerstown series that relatively the same amounts of P_2O_5 are taken up by the plant or fixed by the soil regardless of whether the P_2O_5 is applied to the soil in the form of acid phosphate, floats or Thomas Slag. This is borne out by the average yields for nine years.
6. From the results obtained on plat No. 18, receiving an annual application of 1200 pounds of lime, it is shown that the lime factor plays a more important part than would be expected on soils of this type.

EFFECT OF SOIL MOISTURE ON GROWTH AND MATURITY IN MAIZE

By T. B. Hutcheson and T. K. Wolfe

Any factor which in some way affects the yield of corn is of vast importance to the farmer. The total production of corn in the United States for 1915 (21) was 3,054,535,000 bushels at an average yield of 28.2 bushels per acre as compared with a yield of 2,707,994,000 bushels at an average yield of 28.8 bushels per acre in 1905. The increase in total yield was due largely to increased acreage and not to greater yields per acre. The variation in yield of corn is due to many factors, prominent among which are soil moisture and fertility. Maximum yields depend to a great extent on the time at which the effects of these factors are produced. It is the general opinion among farmers that, although the rainfall may be deficient during the early period of growth of corn, an abundant supply of moisture in later stages will produce a good crop. It is thought that a plentiful supply of moisture is necessary at the time the ear is developing. It has been shown by experiment that different crops have different and definite times at which irrigation water should be applied in order to secure maximum yields.

The variety of corn that matures the latest in a given section usually produces the greatest yield per acre. Thus, the yields of corn in certain states where the growing period is short is limited, due to the fact that an early maturing variety of corn must be planted. It is well known that moisture is a great limiting factor in corn production. Then, if by the application of water in irrigated sections or its conservation in humid sections, a later maturing variety can be grown where formerly earlier maturing varieties were necessarily grown, it will mean a greater profit to the producer.

Review of Literature

Kiesselbach and Montgomery (9) grew corn plants in potometers, holding 260 pounds of moisture-free soil. There were five series of four potometers each. The soil in each series was kept at a different percentage of soil saturation as follows: 100 percent, 80 percent, 60 percent, 45 percent, and 35 percent.. The potometers were weighed daily and the loss of moisture was restored at the time of weighing. The results show clearly

that the plants naturally fall into three classes, one having more than optimum (100 percent), one having the optimum (60-80 percent), and one with less than the optimum (35-45 percent) water content. The following table is taken from Kiesselbach and Montgomery.

Summary of Growth Relationship of Corn. Plants in Five Different Degrees of Soil Moisture

Number of Plants	Saturation Maintained (Percent)	Total Dry Weight of Plant (Grams)	Date Mature
4	100	372.8	Sept. 20
4	80	484.1	Sept. 22
4	60	442.0	Sept. 24
4	45	297.1	Sept. 27
4	35	111.5	Oct. 2

Morgan (12) grew oats in the greenhouse in pots containing loam at 17.6, 29, and 42.8 percent moisture. The increase of soil moisture from 17.6 to 29 percent delayed the time of heading 0.9 of a day, while an increase in moisture from 29 to 42.8 percent delayed heading practically two days over that of 17.6 percent moisture, and three days over that of 29 percent. The greatest average variation in the length of time required for the plants to reach the heading stage, due to increase in soil moisture, was three days. In regard to the production of dry matter, the writer says: "There is an increase in the production of dry matter following an increase in the moisture content of the soil. The increase is more marked following a change from 17.6 to 29.0 percent than from 29.0 to 42.8 percent." The percentage of dry matter decreases as the soil moisture increases.

This same investigator in another experiment with wheat found that plants grown in soil kept at 42.8 percent moisture headed out practically three days later than those grown at 17.6 percent moisture. The higher moisture content increased the length of culms from 26.8 inches to 37.7 inches, the length of spikes, from 3.19 inches to 3.55 inches, and greatly increased the production of both grain and straw. High moisture increased stooling in wheat and decreased it in oats.

Harris (3) irrigated wheat weekly with different quantities of water and at different periods during the growth of the crop. The check produced 37.3 bushels of grain per acre, the plat receiving 1 inch of water weekly produced 44.3 bushel, the one receiving 2½ inches of water weekly 44.6 bushels, the one receiving 5 inches weekly 45.8 bushels, and the plat which received 7½ inches of water weekly produced 43.5 bushels. Thus, 1

inch of water weekly produced almost as much yield as larger quantities and produced a higher yield than 7½ inches weekly. In regard to yield from applications of water at different stages of growth, the best yield for one irrigation was obtained when the water was applied during the first stage; the best yield for two irrigations when the water was applied at the first two stages. The highest yield was obtained when the water was applied at the first three stages. Irrigation at the last stage was the least favorable time. The first stage was the most important time for irrigation, and the last the least important. Five inches of water were applied at each irrigation. As to the date of maturity, the writer says: "In general the plats receiving the higher irrigations had longer growing seasons than those which were not irrigated or which received but little water." The unirrigated wheat matured in 117 days, while that receiving 5 and 7½ inches of water weekly matured in 128 days. Plats receiving only 5 inches of water matured before those obtaining 10, 15 or 20 inches.

Harris (4) shows in the following table that corn grown on higher irrigated plats possesses a longer period of growth than corn grown on plats to which less water was applied.

Effect of Irrigation on the Length of the Growing Period of Corn. Averages of Three Irrigation Treatments

Water Applied	Days from Planting to Maturity
None	121.0
5 inches	124.3
10 inches	126.3
20 inches	126.3
30 inches	126.0
40 inches	128.0

An application of twenty inches of water gave the highest yield of grain per acre. The writer states: "Not only was all the water that was applied over twenty inches wasted, but it actually decreased the amount of corn produced to the acre. The over-irrigation caused a loss of water, a loss of time in applying it, a loss of corn and injury to the soil."

Widtsoe (16, p. 258) states that the ideal condition for growing corn under irrigation is to keep a uniform moisture content at all times. Water should be supplied in abundance at the time of seed formation, but when the seed is ripening little is required. In the later periods of growth, water must be withheld from the plants in order not to delay maturity. This writer says (16, p. 173) in regard to the water requirements of different

crops at different times, that: "Different crops have different water requirements, both as to total quantity and periodic application. Young plants use less water than do the larger and stronger plants some weeks older; and the mature plant, the life activities of which have ceased, has only little need of water. The life history of the plant determines, largely, the best time of irrigation."

Sanborn (14) obtained a yield, the average of four years, of 13.33 bushels of grain (wheat) and 1135 pounds of straw from early and late irrigation as compared with 10.04 bushels of grain and 1097 pounds of straw from usual watering. Unwatered plats yielded 4.5 bushels of grain and 495 pounds of straw per acre. In all four years the early and late and usual watered plats were harvested on the same date; the unwatered plats were harvested five to fourteen days earlier. Early irrigation increased the yield of wheat and decreased the yield of straw. In case of oats, early watering each succeeding year decreased the yields of both the grain and straw, except in one instance, the straw was greater from early watering.

Harris (5) in growing wheat plants, shows that, "in drier soils, the lowest relative transpiration is found when the plants had grown from twelve to sixteen weeks. From this point on to maturity, they used relatively more water, but never as much as during the first few weeks of growth." The amount of soil moisture varied from 11 to 45 percent. Using 30 percent of soil moisture as a basis of comparison, the greatest relative dry weight of straw and grain and of grain was obtained at 37½ percent soil moisture.

Briggs and Shantz (1) find that: "The transpiration of the annual crop plants (aside from fluctuations due to weather) rises to a maximum a little beyond the middle of the growth period and then decreases until the plants are harvested. Perennial forage crops, such as alfalfa, increase steadily in transpiration to a maximum at or near the time of cutting. Various crops show their individuality by departing more or less from these types."

Khankhoje (7) shows that wheat plants require more water in the first period (fifty days after germination) of their growth than in the second (ninety days after germination) and more in the second than in the third period (137 days after germination).

The following table showing the weight of corn plants grown in soil kept at different percentages of soil saturation was secured from the twenty-third annual report of the Nebraska Station (9).

Data Showing Average Total Weight of Corn Plants Minus Roots, and Average Total Weight Including Roots Under Different Moisture Conditions

Number of Plants	Saturation Maintained with 5-10 Percent Variation (Percent)	Average Total Weight Minus Roots (Grams)	Average Total Weight Including Roots (Grams)
4	98	91.1	101.7
4	80	93.1	106.8
4	60	100.6	114.5
4	40	92.9	108.1
4	20	83.2	99.0

The following table is taken from Kiesselbach (10).

Summary Showing the Growth Relationship of Corn in Different Degrees of Soil Moisture During Two Years, 1913 and 1914

Year	Relative Saturation (Percent)	No. of Potometers Averaged	Total Dry Matter (Grams)
1913	50	7	233.86
	70	8	407.63
	95	8	372.00
1914	50	4	512.00
	50*	4	619.75
	70	4	560.50
	70*	4	674.25
	95	4	488.25
	95*	4	520.00
	⅔ of 70†	4	492.50
	⅔ of 70*†	4	493.25

*With 1.75 pounds of moisture-free sheep manure added.

†Started at 70 percent (optimum) water content and received each day thereafter only two-thirds as much water as was transpired by the average of eight plants in soil constantly 70 percent saturation.

Kiesselbach finds that shortage of moisture existing in an average relative saturation of 49 percent, decreased the yield of total dry matter 30.7 percent, excess of moisture, existing in an average relative saturation of 97 percent, decreased the yield of total dry matter 16.7 percent. The basis of comparison is 70 percent of moisture. The application of manure to the soil with a shortage of moisture increased the yield of dry matter 21 per-

cent. The addition of manure to the soil containing 70 and 95 percent of saturation increased the yield of total dry matter. The reduction of the water by one-third resulted in a decrease of 14 percent in yield of dry matter; manure seemed to have had but little effect in this instance.

Yuncker (22) in growing corn plants in soil holding 25, 45, and 65 percent of moisture, found that the lowest moisture content gave the highest yield of dry matter, the highest moisture content the lowest yield and the intermediate soil moisture was intermediate in yield of dry matter when the plants were grown for 35 days. When the plants were grown for 55 days the reverse was true.

Miller (11) found that the average dry weight of leaves and stems of five corn plants was 11.5 grams at one month from time of planting, 51 grams at six weeks from time of planting, 128.7 grams at eight weeks, and 178.5 grams at ten weeks from time of planting, or when the leaf growth was completed. These data should give some indications as to when the corn plant requires the most abundant supply of water. At the time of most rapid growth larger quantities of water will be needed for carrying on the functions of the plant.

Briggs and Shantz (2) have reviewed a large amount of literature in regard to the water requirements of plants. Included in this review is literature pertaining to the effect of soil moisture content on the water requirement, in which is usually given the amount of dry matter produced under different percentages of soil moisture.

In Oregon (13) the most profitable time for the application of irrigation water to the corn crop is just previous to the time that the maximum growth takes place. It is recommended that one three-inch application of water be given in wet seasons or about twice this much in two applications in dry seasons.

Sanborn (15) showed that very early watering was not economical in case of wheat and oats. The ratio of grain to straw was increased, but the total yield was not increased. Very late watering increased the ratio of grain to straw as well as the total yield.

Widtsoe and Merrill (18) found that the yield of corn increased as the amount of water was increased up to 25 inches, then a decrease followed with larger applications of water. The amount of stover increased as the amount of water increased to 55 inches, except in case of 7½ inches, the yield was larger than when 10 inches was applied. An application of 55 inches gave a smaller yield than a 30-inch application.

Widtsoe (17) obtained results which show that "doubling the saturation degree increased the yields of wheat, corn and peas about 2¼ times and the yield of sugar beets over three times." The percentages of saturation used were 10, 15, and 20 percent.

Widstoe and Stewart (19) found on applying different quantities of irrigation water to wheat, sugar beets, oats, and potatoes at different periods of growth, that the crop producing power of water at an early period of growth was much less than at later periods. "In the early stages of their growth, then, plants need only small quantities of water, more being required as they approach the time of ripening, after which smaller amounts will be ample." These same writers (20) showed that the total yield of ash per acre in the corn kernel did not materially increase with increase of water. Twenty inches of water produced 34 pounds more ash per acre than 7½ inches, and the yield for 10 and 15 inches of water was intermediate. The ash in the stover increased until 30 inches of water was applied; a decrease resulted with an application of 55 inches of water. In case of protein in the corn kernel, there was a slight increase in amount of protein produced per acre by increasing water up to about 30 inches, then there occurred a reduction. In case of stover, the yield of protein was materially increased with an application of 10 inches of water as compared with 7½ inches. With applications greater than 10 inches the yield was practically constant.

Harris (16) found that the green weight of the tops of corn plants increased as the water content was increased from 11 to 38 percent of soil moisture. The following table is given by this writer.

Green Weight of Tops of Corn Plants Grown in Quartz Sand Containing Different Amounts of Water

Percent Water	Green Weight in Grams
38	3.63
30	3.54
20	3.36
15	2.35
11	1.56

STATEMENT OF PROBLEM

The purpose of the experiment here reported was to determine the effect of high and low percents of soil moisture through the grand period of growth and at different periods of development of the corn plant on maturity and yield.

Materials and Methods Used

The soil used was about an equal mixture of Hagerstown silt loam from the experiment plats, and greenhouse soil that had been composted and was high in organic matter. The soil was thoroughly mixed and the water-holding capacity determined. Thirty-two galvanized iron pots, 11 1/8 inches in diameter and 14 inches in height, each with a tube on the side for the addition of water, were divided into eight series for this work. To each pot was added nineteen kilograms of the air-dry soil and four kilograms (1 3/4 inches) of sand and gravel mulch. At the proper time one kernel ot Boone County White Corn was placed in the soil in each pot under the mulch. All of these kernels came from the same ear. The pots were covered with tight-fitting wooden covers, each cover having a two-inch hole in the center to allow for the emergence of the plant. The hole in the cover and that in the tube on the side were closed with cotton to prevent evaporation. The cotton in the hole in the cover was removed to permit emergence of the plant, and after the plant had fully emerged the cotton previously removed was placed around the plant.

As stated before, the pots were divided into eight series of four pots each; each series received a different moisture treatment as enumerated below.

Series

I—The corn was started in soil at 70 percent saturation and kept at this point until the plant in pot 3 was one week old, in pot 1 two weeks old, in pot 2 three weeks old, and pot 4 four weeks old. Then the moisture was allowed to recede until the wilting point was reached. As soon as the temporary wilting point was reached, the moisture was increased to 70 percent saturation and maintained at this percent until maturity.

II—The corn was grown to maturity in soil at 70 percent saturation.

III—The corn was grown to maturity in soil at 40 percent saturation.

IV—The corn was grown to tasseling in soil at 70 percent saturation and then the moisture was reduced to 40 percent for the remainder of the period.

V—The corn was grown to tasseling in soil at 40 percent saturation and then the moisture increased to 70 percent saturation for the remainder of the period.

VI—The corn was grown for the first six weeks in soil at 70 percent saturation and then the soil moisture was reduced to 40 percent saturation for the remainder of the period.

VII—The corn was grown for the first six weeks in soil at 40 percent saturation and then the moisture was increased to 70 percent saturation for the remainder of the period.

VIII—The corn was started in soil at 70 percent saturation, which was allowed to recede to 40 percent saturation. Whenever the moisture decreased to 40 percent it was increased to 70 percent saturation.

The corn was planted on December 6, 1915, and daily weighings were taken from that time until maturity. The loss of water was replaced at each weighing, or whenever called for in the outline. The temperature was kept as near as practicable to that at which corn grows in the field. Notes were taken from time to time on the appearance of the plants and the time of tasseling, maturity of pollen and silking. All changes of moisture content were made at the time stated in the outline. As soon as the plants of one series matured all of the plants in each series were harvested, and notes were taken on their comparative maturity. After harvesting, the green and dry weights were obtained and the total moisture found in order to calculate the amount of material produced on an absolute dry basis.

Results of the Experiment

In Table I are presented data showing the number of days from the appearance of each individual plant to tasseling, silking, and to maturity of pollen; also the height of the plant in inches at time of tasseling. The measurements were taken from the soil to the end of the longest leaf.

Table I.—*Number of Days from Appearance of Plant to Tasseling, Silking, Maturity of Pollen; and Height in Inches at Tasseling*

Series No.	Treatment	Plant No.	Days from Appearance of Plant to: Tasseling	Silking	Pollen Maturity	Height at Tasseling
I	Allowed to wilt when 2 weeks old and increased to 70 percent saturation	1	82	94	86	66¼
	Allowed to wilt when 3 weeks old and increased to 70 percent saturation	2	81	89	82	60¼
	Allowed to wilt when 1 week old and increased to 70 percent saturation	3	Died before tasseling			
	Allowed to wilt when 4 weeks old and increased to 70 percent saturation	4	79	90	80	56¾
II	Grown to maturity at 70 percent saturation	5	74	95	86	64¼
		6	82	102	82	73
		7	81	86	81	61¾
		8	68	86	80	66¾
III	Grown to maturity at 40 percent saturation	9	82	100	84	53½
		10	85	99	92	60¼
		11	86	99	88	56¾
		12	85	96	89	58¼
IV	Grown to tasseling at 70 percent saturation and then reduced to 40 percent	13	83	92	88	71¾
		14	71	91	83	67½
		15	81	95	82	75¾
		16	67	87	80	74¼
V	Grown to tasseling at 40 percent saturation and then increased to 70 percent	17	90	104	98	49½
		18	84	98	90	60
		19	84	92	86	56¼
		20	100	105	102	54
VI	Grown for first 6 weeks at 70 percent saturation and then reduced to 40 percent	21	73	93	80	58¾
		22	87	105	91	68
		23	81	92	90	59½
		24	92	103	95	66½
VII	Grown for first 6 weeks at 40 percent saturation and then increased to 70 percent	25	87	102	95	64¾
		26	96	107	99	61¼
		27	82	96	91	59¾
		28		Died		
VIII	Started at 70 percent saturation and allowed to decrease to 40 percent. Whenever moisture decreased to 40 percent, increased to 70 percent saturation	29	79	91	82	70
		30	84	93	84	64¾
		31	80	94	86	68½
		32	69	87	80	62¼

TABLE II.—*Average Number of Days from Appearance of Plants to Tasseling, Silking and Maturity of Pollen, and Average of the Three Series of Days for Series 2 to 8 Inclusive*

Series No.	Average Number of Days from Appearance of Plants to			Average of the 3 Dates
	Tasseling	Silking	Maturity of Pollen	
II	76¼	92¼	82¼	83 7/12
III	84½	98½	88¼	90 5/12
IV	75½	91¼	83¼	83⅓
V	89½	99¾	94	94 5/12
VI	83¼	89¼	89	90⅙
VII	88⅓	101⅔	95	95
VIII	78	91¼	83	84 1/12

TABLE III.—*Variation in Days between Individual Plants of Each Series for Tasseling, Silking and Pollen Maturity*

Series No.	Tasseling	Silking	Pollen Maturity
1	3	5	6
II	14	16	6
III	4	4	8
IV	16	8	8
V	16	13	16
VI	19	13	15
VII	14	11	8
VIII	15	7	5

The variation in days in Table III denotes the time which elapsed between the first and last plant to tassel, silk and mature pollen within each series. These dates are presented to show the great variation which may occur in corn plants, even in those from seed from the same portion of the same ear, and from a seed supply that is known to be "pure."

Using Series II as the basis of comparison, in Table IV is shown the variation between the average time of tasseling, silking, pollen maturity and the average of these averages of series 2 and 8.

Table IV.—*Variation in Days between Series in the Average Time of Tasseling, Silking, Maturity of Pollen and Average of the Averages*

Series No.	Tasseling	Silking	Pollen Maturity	Averages of Variation
II	......	......	......	......
III	8 1/4	6 1/4	6	6 5/6
IV	-3/4	-1	1	-1/4
V	13 1/4	7 1/2	11 3/4	10 5/6
VI	7	6	6 3/4	6 7/12
VII	12 1/12	9 5/12	12 3/4	11 5/12
VIII	1 3/4	-1	3/4	1/2

If in Table IV we compare Series II in which the corn plants were grown to maturity at 70 percent of saturation, and Series III in which the corn plants were grown to maturity at 40 percent of saturation, we find that the plants in Series II matured 6 5/6 days before those in Series III. From the Nebraska experiments on the water requirements of the corn plant (8) it is found that 60 to 80 percent of saturation is the optimum soil moisture content while 40 percent is sub-optimum.

The plants in Series II and IV matured at practically the same time. It seems from this that the critical time in regard to soil moisture as far as maturity is concerned is the period from planting to the time of tasseling. That is, provided the soil moisture has been at the optimum to time of tasseling, the decrease of the amount of soil moisture within certain limits, after tasseling does not affect the time of maturity. From this we would draw the conclusion that if in the stages of growth up to tasseling, the moisture content has been at an optimum, the functions of the plant have been carried on to such an extent that the plant does not require the optimum amount of moisture after tasseling. On comparing Series II with Series V, we find that the plants in the latter series matured 10 5/6 days later than those in Series II. In Series V, the soil moisture was kept at 40 percent of saturation to tasseling and then increased to 70 percent. That is, an optimum supply of moisture near the end of the growing period delayed maturity, provided the soil moisture had previously been deficient. The increased moisture at the end of the growing period renewed plant growth and gave the plants increased vigor. The low moisture content of the soil limited the development of the plants. On the other hand, the optimum moisture content at all times in Series II allowed the plants to develop rapidly from the start. The plants in Series VI matured 6 7/12 days later than those in Series II. The difference in time of maturity is still greater when we compare the plants of Series VII with those of Series II.

The plants of the former Series matured 11 5/12 days later than those of Series II. In this instance, as in the case where Series II is compared with Series V, an application of increased amounts of moisture toward the end of the growing period delayed maturity. Although in Series VII the amount of moisture was limited only for the first six weeks, we find a delay of 11 5/12 days in maturity as compared with the plants which had the optimum soil moisture content throughout their growth. The plants of Series II and VIII matured in about the same time. Alternate wetting and drying within the limits of soil moisture used in this experiment (40 percent and 70 percent of saturation) did not affect maturity as compared with those plants growing under an optimum moisture condition at all times. The conditions of Series VIII are nearer those found in nature than that of Series II.

When we compare Series III with Series IV, it is found that the plants of the former series matured 7½ days later. The plants of Series V matured four days later than those in Series III. The plants of Series VI matured in practically the same time as those of Series III. The increased moisture at the beginning of the period did not hasten or retard maturity as compared with the series in which water was deficient at all times. The plants of Series IV matured 7 1/12 days before those of Series III, indicating again that the critical time in regard to early maturity, as far as moisture is concerned, is somewhere between the time the plant is six weeks old and the time of tasseling. On comparing the plants of Series III and VII, we find that those of the latter series matured 4 7/12 days later. This shows that if the soil moisture is to be at the optimum after the first six weeks, it must be at the optimum during the first six weeks in order to secure earlier maturity. The plants of Series III matured 6 1/3 days later than those of Series VIII. This proves again that allowing the soil moisture to recede to 40 percent of saturation is not injurious, provided it is immediately raised to the optimum. However, if the plants are allowed to remain at 40 percent of saturation throughout the period of growth, maturity is retarded. Series IV matured 11 1/12 days before Series V. The difference in maturity was very noticeable. Series IV matured 6 5/6 days before Series VI. This also shows that for early maturity the optimum moisture content should be continued until tasseling. However, the optimum content for the first six weeks hastens maturity more than if the moisture is deficient for the first six weeks and brought to the optimum afterwards. Series VII matured 11 2/3 days after Series IV. Series IV and VIII matured at practically the same time. Series V matured 4 1/4 days later than Series VI. In Series VI the optimum moisture content was applied at the beginning of growth. Series V and Series VII matured at practically the same time. In both cases the moisture was deficient in the first stages; in the former until time

of tasseling, and for the first six weeks in the latter. This again emphasizes the importance of an abundant supply of moisture even in the very early stages of growth, as both of these Series are later than those in which the moisture supply was abundant in the early stages. Series III matured 9 11/12 days before Series V. Series VI matured 4 5/6 days before Series VII. In the former the optimum supply of moisture was applied during the first six weeks and in the latter after the first six weeks. Series VI matured 6 1/12 days later than Series VIII. Series VIII matured 10 11/12 days before Series VII. The series matured in the order named:

Series
- IV*—Plants grown to tasseling in soil kept at 70 percent of saturation and then decreased to 40 percent of saturation for remainder of period.
- II*—Plants grown to maturity in soil kept at 70 percent of saturation.
- VIII*—Plants started in soil at 70 percent saturation and allowed to recede to 40 percent, and whenever 40 percent was reached the soil moisture was increased to 70 percent of saturation.
- VI†—Plants grown for first six weeks in soil kept at 70 percent saturation and then allowed to recede to 40 percent of saturation for remainder of period.
- III†—Plants grown to maturity in soil kept at 40 percent saturation.
- V‡—Plants grown to tasseling in soil kept at 40 percent of saturation and then increased to 70 percent for the remainder of the period.
- VII‡—Plants grown for first six weeks in soil kept at 40 percent of saturation and then increased to 70 percent for the remainder of the period.

In Table V are presented data showing the moisture-free weight of each plant, and total moisture-free weight of plants for each series.

*Series II, IV and VIII matured in practically the same time.
†Series III and VI matured in practically the same time.
‡Series V and VIII matured in practically the same time.

TABLE V.—*Moisture-Free Weight of Each Plant and Total Weight of Each Series*

Series No.	Plant No.	Moisture-Free Weight of Plants (Grams)	Total Weight of Each Series (Grams)
I	1	152.07	459.61
	2	95.66	
	4	96.98	
II	5	177.26	645.24
	6	146.82	
	8	159.85	
III	9	75.48	294.11
	10	75.74	
	11	57.61	
	12	85.28	
IV	13	106.48	458.82
	14	115.50	
	15	93.24	
	16	143.60	
V	17	68.12	420.17
	18	112.24	
	19	115.15	
	20	124.66	
VI	21	115.28	486.86
	22	131.61	
	23	120.89	
	24	119.08	
VII	25	107.92	432.96
	26	104.98	
	27	111.82	
VIII	29	138.24	515.30
	30	124.25	
	31	132.47	
	32	120.34	

In Series I, II and VII one-third of the total weight of the three plants was added to obtain the total given. This was done to make these series comparable with the others. Plants 3 and 28 died before maturity, and due to the fact that it was necessary to replant pot 7 twice, the plant produced reached final maturity much later than the others and was discarded as far as yield was concerned.

In Table VI is shown the total weight of the plants of each series and the percentage of weight of each series as compared with Series II.

TABLE VI.—*Total Weight and Percentage of Weight of Each Series as Compared with Series II*

SERIES NO.	TOTAL WEIGHT OF EACH SERIES (Grams)	PERCENTAGE OF WEIGHT OF EACH SERIES AS COMPARED WITH SERIES II
I	459.61	71.23
II	645.24	100.00
III	294.11	45.58
IV	458.82	71.11
V	420.17	65.12
VI	486.86	75.45
VII	432.96	67.10
VIII	515.30	79.86

In Table VII are presented data showing the relation between time of maturity and weight of plants.

TABLE VII.—*Relative Weights and Time of Maturity of Series II to VIII*

SERIES NO.	RELATIVE TIME OF MATURITY	RELATIVE WEIGHTS
II	2	1
III	5	7
IV	1	4
V	6	6
VI	4	3
VII	7	5
VIII	3	2

Referring to Table VI it will be seen that Series II gave the highest yield of dry matter (weight of plant). This series matured practically as soon as Series IV which was the first to mature. Series II was grown under optimum soil moisture conditions. The second highest yield in dry matter was made by Series VIII, in which the soil was allowed to be alternately wet and dry. This series yielded 20.14 percent less than Series II. Series I and IV yielded practically the same amount of dry matter, being 28.77 percent and 28.89 percent, respectively, below Series II. In Series I the plants were allowed to undergo a period of wilting followed by optimum soil moisture, while in Series IV the plants were grown to tasseling in soil at 70 percent of saturation and then reduced to 40 percent for the remainder of the period. These series rank fourth in amount of dry matter produced. Series VII, in which the soil was kept at 40 percent saturation for the first six weeks, and then increased to 70 percent, stood fifth in regard

to yield, or 32.90 percent below Series II. Series VI, in which the moisture was high for the first six weeks and low the remainder of the period, stood third in regard to yield, or 24.55 percent below Series II. This is contrary to the opinions of farmers, who say that the most important time for abundance of moisture for producing high yield of corn is at earing time. It is a common saying among corn growers that although rainfall may be deficient in the early part of the corn growing season, yet if there is plenty of rain at the time the grain is forming there will be a good crop of corn. Series V was sixth in regard to yield, being 34.88 percent below Series II. Series III stood last, being 54.42 percent below Series II. Series IV obtained optimum amount of moisture to tasseling, while Series VI obtained optimum moisture during the first six weeks. The average percent of loss in yield of these two series is 26.72. Series V obtained optimum amount of moisture after tasseling, while Series VII obtained optimum moisture after the first six weeks. The average percent of loss in yield of these two series was 30.685. Thus, Series V and VII lost on the average 3.965 percent more in yield than did Series IV and VI. It is interesting to note that Series IV was the first series to mature, Series VI matured 6 5/6 days later than Series IV, while Series V and VII were 11 1/12 and 11 2/3 days, respectively, later than Series IV.

Thus, leaving out of consideration Series I, II, III and VIII, the conclusion which we draw from this experiment is that for both early maturity and high yield of dry matter (weight of plant) optimum soil moisture content should be present in the early stages of growth of the corn plant. The critical time, so far as soil moisture is concerned in the growth of corn, is in the early period of the growth of the plant. Lack of optimum soil moisture even in the first six weeks retards maturity and lessens the yield of dry matter. However, it must be borne in mind that this experiment was conducted under greenhouse conditions.

Effect of Wilting on Maturity

In Series I the plants were allowed to reach the stage of temporary wilting, and when this stage was reached the plants were brought to 70 percent of saturation and grown at this soil moisture for the remainder of the period. In this series there were four plants, and in order to study the effect on maturity of the age at which plants are started in the wilting period, each plant was allowed to enter this period at a different age.

In Table VIII is shown the age of plants when the period of wilting began, date of beginning and ending of the wilting period, amount of water lost by each plant, wilting coefficient, and number of days to maturity.

TABLE VIII.—*Age of Plant at Beginning of Wilting Period, Date Wilting Started and Ended, Amount of Water Lost, Wilting Coefficient, and Number of Day to Maturity (average of tasseling, silking and pollen maturity)*

SERIES NO.	PLANT NO.	AGE OF PLANT IN WEEKS	DATE WILTING PERIOD BEGAN AND ENDED	AMOUNT OF WATER LOST BY EACH PLANT (Grams)	WILTING COEFFICIENT (Percent)	AVERAGE NUMBER OF DAYS TO MATURITY
	1	2	Dec. 29, '15–Feb. 17, '16	3221	12.59	87½
	2	3	Jan. 6, '16–Feb. 21, '16	3258	12.35	84
I	3	1	Jan. 4, '16–Feb. 22, '16	3098	13.37	Died
	4	4	Jan. 12, '16–Feb. 17, '16	3283	12.19	83

In Table IX are shown the percentage of water and moisture and the moisture-free weight of each plant in Series I.

TABLE IX.—*Percentage of Water and Moisture and Moisture-Free Weight in Grams of Each Plant of Series I*

PLANT NO.	PERCENTAGE OF		MOISTURE—FREE WEIGHT (Grams)
	WATER	MOISTURE	
1	70.81	4.30	152.07
2	73.14	5.47	95.66
3	Died before maturity		
4	70.81	4.41	96.98

On account of the small number of plants a discussion of Tables VIII and IX would be out of place, but the data are given as a matter of interest.

SUMMARY

1. For early maturity and high yield in the corn plant, optimum soil moisture should be present throughout the period of growth.

2. Alternate wetting and drying of the soil produces early maturity of the corn plant and high yield of dry matter second only to those plants grown under optimum conditions of soil moisture.

3. Contrary to the opinion of many corn growers, the highest yields of dry matter are obtained when optimum soil moisture is present in the early stages of growth of the plant, rather than at earing time. This condition also hastens maturity.

4. The critical time in the life of the corn plant in regard to both early maturity and high yields, as far as soil moisture is concerned, is in the early stages of growth.

5. The optimum soil moisture content in the later stages of growth of the corn plant, following periods of low soil moisture, retards maturity and lessens the yield.

6. This experiment was carried on in pots in the greenhouse and whether these results would apply to field conditions, the writers cannot say.

LITERATURE CITED

1. Briggs, Lyman J., and Shantz, H. L.—Daily Transpiration During the Normal Growth Period and Its Correlation with the Weather. Jour. Agr. Res. **7**: 155-212. 1916.
2. Briggs, Lyman J., and Shantz, H. L.—The Water Requirements of Plants. Part. II.—A Review of the Literature. U. S. Dept. Agr. Bu. Plant Ind. Bul. **285.** 1913.
3. Harris, F. S.—The Irrigation of Wheat. Utah Agr. Exp. Sta. Bul. **146.** 1916.
4. Harris, F. S.—Irrigation and Manuring Studies. The Effect of Varying Quantities of Irrigation Water and Manure on the Growth and Yield of Corn. Utah Agr. Exp. Sta. Bul. **133.** 1914.
5. Harris, F. S.—Long *versus* Short Periods of Transpiration in Plants Used as Indicators of Soil Fertility. Proc. Amer. Soc. Agron. **2**: 93-102. 1910.
6. Harris, F. S.—The Effect of Soil Moisture, Plant Food and Age on the Ratio of Tops to Roots in Plants. Jour. Amer. Soc. Agron. **6**: 65-75. 1914.
7. Khankhoje, P. S.—Some Factors which Influence the Water Requirements of Plants. Jour. Amer. Soc. Agron. **6**: 1-23. 1914.
8. Kiesselbach, T. A., and Montgomery, E. G.—The Relation of Climatic Factors to the Water Used by the Corn Plant. Nebr. Agr. Exp. Sta. 24th Ann. Rept., pp. 91-107. 1911.
9. Kiesselbach, T. A.—Transpiration Experiments with the Corn Plant. Nebr. Agr. Exp. Sta. 23d Ann. Rept., pp. 125-139. 1909.
10. Kiesselbach, T. A.—Transpiration as a Factor in Crop Production. Nebr. Agr. Exp. Sta., Res. Bul. **6.** 1916.
11. Miller, Edwin C.—Comparative Study of the Root Systems and Leaf Areas of Corn and the Sorghums. Jour. Agr. Res. **6**: 311-331. 1916.
12. Morgan, J. Oscar—The Effect of Soil Moisture and Temperature on the Availability of Plant Nutrients in the Soil. Proc. Amer. Soc. Agron. **3**: 191-249. 1911.

13. Powers, W. L.—Irrigation and Soil Moisture Investigations in Western Oregon. Ore. Agr. Exp. Sta. Bul. **122.** 1914.
14. Sanborn, J. W.—Irrigation: Early. Late and Usual. Utah Agr. Exp. Sta. Bul. **27.** 1894.
15. Sanborn, J. W.—Early *versus* Late Irrigation. Utah Agr. Exp. Sta. Bul. **23**: 11-14. 1893.
16. Widtsoe, John A—Principles of Irrigation Practice. pp. 258 and 173. The MacMillan Company, New York. 1914.
17. Widtsoe, John A.—Irrigation Investigations. Factors Influencing Evaporation and Transpiration. Utah Agr. Exp. Sta. Bul. **105.** 1909.
18. Widtsoe, John A., and Merrill, L. A.—The Yields of Crops with Different Quantities of Irrigation Water. Utah Agr. Exp. Sta. Bull **117.** 1912.
19. Widtsoe, John A., and Stewart, Robert—The Effect of Irrigation on the Growth and Composition of Plants at Different Periods of Development. Utah Agr. Exp. Sta. Bul. **119.** 1912.
20. Widtsoe, John A., and Stewart, Robert—The Chemical Composition of Crops as Affected by Different Quantities of Irrigation Water. Utah Agr. Exp. Sta. Bul. **120.** 1912.
21. Yearbook. U. S. Dept. Agr., p. 412. 1915.
22. Yuncker, T. G.—A Study of the Relation of Soil Moisture to Transpiration and Photosynthesis in the Corn Plant. Plant World **20**: 151-161. 1916.

PART I—THE EFFECT OF DIFFERENT PLANT TISSUES ON THE FIXATION OF ATMOSPHERIC NITROGEN[1]

By T. J. MURRAY[2]

Winongradski, in 1893, first demonstrated the presence of an anaerobic organism capable of fixing atmospheric nitrogen in the soil. In 1901, Beyerinck showed that the fixation was also carried out by an aerobic group of organisms—the azotobacter. These two groups of organisms live a non-symbiotic life and are thus distinguished from the nitrogen-fixers that live in symbiosis with the legumes.

It is known that if a certain amount of carbohydrate or similar substance is added to a soil, it supplies these micro-organisms with a source of carbon and stimulates the fixation of atmospheric nitrogen. The amount of nitrogen fixed per gram of substance varies. Haselhoff and Bredemann (1906), working with pure cultures and mixed cultures, found from .42 to 4.72 milligrams of nitrogen fixed per gram of mannite. Lipman (1908) found from .39 to 10.45 milligrams of nitrogen fixed per gram of mannite, by pure cultures of azotobacter in four weeks.

In soils, these micro-organisms must have a source of energy. Their source of carbon may come from the disintegrated roots of plants or the broken down plant tissue. The aim of this work was to find out whether different plant tissues, such as alfalfa, oat straw, cabbage, etc. serve as a source of carbon and influence the fixation of atmospheric nitrogen by these soil micro-organisms.

In this work twenty-one substances were used: Tall oat grass (Arrhenatherum elatius), Sudan grass (Andropogan sorghum), rye grass (Elymus sp.), timothy (Phleum pratense), blue grass (Poa pratensis), wheat (Triticum vulgare), corn (Zea mays), broom sedge (Andropogon virginicus), red top (Agrostis vulgaris), oat grass (Arrhenatherum), sorghum (Andropogon sorghum), millet (Panicum miliaceum), cowpeas (Vigna Sinensis), soybeans (Soja hispida), peas (Pisum sativum), hairy vetch (Vicia sativa), alsike clover (Trifolium hybridum), alfalfa (Medicago sativa), tomato (Lycopersicum esculentum), artichoke (Helianthus tuberosus), and cabbage (Brassica oleracea). The tissue was dried and ground up in a mill. One percent of these test substances was added to each of three one-quart mason jars, containing 300 grams of sieved Hagerstown silt loam. The moisture content was adjusted; the jars were weighed

[1]Paper No. 52 from the Laboratories of Plant Pathology and Bacteriology, Va. Agr. Exp. Station.

[2]This work was started with Mr. K. E. Quantz, formerly of the Station.

and the weight recorded on the label. They were then incubated at 28° C. The moisture content was adjusted weekly. Total nitrogen determinations (modified Gunning method), Hibbard (1910), were run in duplicate on ten-gram dry samples after two, four and six months intervals. In taking a sample, the three hundred grams of soil in a jar were well shaken to insure mixing and then 100 grams of this mixture were weighed out. This was dried under 100° C. and two approximately ten-gram samples were weighed and the determination continued. Total nitrogen determinations on checks to which no plant tissue had been added, were run at the same intervals. These checks received the same treatment as the other jars with the exception that no plant tissue was added.

TABLE I.—*Total Nitrogen Determinations. Nitrogen in Milligrams per 10 Grams of Soil. Each Amount Represents the Average of Two Determinations*

Test Substance	At Beginning	After 2 Months	After 4 Months	After 6 Months
Oat Grass	12.91	11.79	17.87	20.27*
Sudan Grass	12.46	13.09	20.93*	20.86
Timothy	12.46	14.74	20.31*	20.10
Millet	13.36	20.94*	19.13	20.45
Rye Grass	12.34	11.73	21.89*	19.98
Blue-Grass	12.67	13.02	21.17*	20.87
Broom Sedge	12.46	12.15	21.56*	21.24
Red Top	12.25	13.70	19.41	20.38*
Tall Oat Grass	12.64	16.66	20.42*	20.18
Sorghum	12.81	11.91	20.20	20.72*
Wheat	12.74	12.92	22.82*	19.10
Corn	12.68	11.73	22.04*	20.21
Cowpeas	13.44	14.96	22.63*	20.71
Soybeans	12.68	12.49	17.04	20.64*
Peas	12.25	12.97	21.22*	18.84
Hairy Vetch	13.79	12.92	16.96	20.51*
Alsike Clover	13.86	15.03	22.04*	21.95
Alfalfa	14.56	12.67	20.08	20.56*
Artichoke	12.11	13.69	22.18*	21.44
Tomato	14.84	13.93	21.03	22.32*
Cabbage	13.44	12.93	21.41*	20.50
Check	12.04	11.70	18.43	18.89*

*The period at which greatest nitrogen fixation occurred.

TABLE II.—*Increase or Decrease in Nitrogen. Nitrogen in Milligrams per 10 Grams of Soil. The Minus Sign Indicates Decrease*

TEST SUBSTANCE	AFTER TWO MONTHS	AFTER FOUR MONTHS	AFTER SIX MONTHS
Oat Grass	-1.12	4.96	7.36*
Sudan Grass	.63	8.47*	8.40
Timothy	2.28	7.85*	7.64
Millet	7.58*	5.77	7.09
Rye Grass	-.61	9.55*	7.64
Blue-Grass	.35	8.50*	8.20
Broom Sedge	-.49	8.92*	8.60
Red Top	1.45	7.16	8.13*
Tall Oat Grass	1.61	4.37	5.13*
Sorghum	-.90	7.39	7.91*
Wheat	.18	10.08*	6.36
Corn	-.95	9.36*	7.53
Cowpeas	1.52	9.19*	7.27
Soybeans	-.19	4.36	7.98*
Peas	.72	8.97*	6.59
Hairy Vetch	-.87	3.17	6.54*
Alsike Clover	1.17	8.18*	7.09
Alfalfa	-1.99	5.42	6.00*
Artichoke	1.58	10.07*	9.33
Tomato	-.91	6.09	7.88*
Cabbage	-.51	7.97*	7.06
Check	-.34	6.39	6.85*

*The period at which greatest increase occurred.

It is at once apparent that nitrogen fixation takes place with all the twenty-one test substances as well as in the case of the checks. After two months, in a great many cases, there is a falling off in the total nitrogen content instead of an expected increase. This does not continue after the four and six-month intervals, as a vigorous fixation is definitely shown.

It is likely that in the case of the checks a source of energy is supplied to the bacteria by the small pieces of plant tissue, roots, etc., that pass through the sieve. It is of course impossible to eliminate these materials, using soil as a medium.

It is noticeable that after a certain amount of nitrogen is fixed or a certain degree of nitrogen is obtained, there is a falling off in the nitrogen content. C. B. Lipman and Burgess (1915) remarked that as a rule, a high nitrogen content seemed to militate against a vigorous fixation. Generally the high point of nitrogen is confined to the fourth month or to the sixth month period. In only one case, (millet) was the high point confined to the second month period.

On the surface it would appear that were we to substract the increase in nitrogen in the checks from the increase in nitrogen in the twenty-one

test substances, that these figures would represent the increase in nitrogen or the increment due to the added material. These results are shown in Table IV.

After a sample has attained a certain degree of nitrogen content, instead of increasing, it often decreases. In some cases the high point of nitrogen fixation occurs after the four-month period and in some after the six-month interval. It would be fair, then, if the highest increase in nitrogen in the check were subtracted from the highest increase in each of the twenty-one test substances. These figures would represent somewhat better the increase in nitrogen, due to the added substance, These results are shown in Table V.

Using soil as a medium the stimulating effect of almost all of the twenty-one test substances is clearly shown. Only three substances failed to show a stimulating effect.

TABLE III.—*Increase or Decrease in Nitrogen over Checks at Different Intervals. Nitrogen in Milligrams per 10 Grams of Soil. The Minus Sign Indicates Decrease*

TEST SUBSTANCE	AT BEGINNING	AFTER 2 MONTHS	AFTER 4 MONTHS	AFTER 6 MONTHS
Oat Grass	.87	.09	–.56	1.38
Sudan Grass	.42	1.39	2.50	1.97
Timothy	.46	3.04	1.88	1.21
Millet	1.32	8.24	.70	1.56
Rye Grass	.30	.03	3.46	1.09
Blue-Grass	.63	1.32	3.74	1.98
Broom Sedge	.42	.45	3.13	2.35
Red Top	.21	2.00	.98	1.49
Tall Oat Grass	3.01	4.96	1.99	1.29
Sorghum	.77	.21	1.77	1.83
Wheat	.70	1.22	4.39	.21
Corn	.64	.03	3.61	1.32
Cowpeas	1.40	3.26	4.20	1.92
Soy Beans	.44	.79	–1.39	1.65
Peas	.21	1.27	2.79	–.05
Hairy Vetch	1.75	1.22	–1.47	1.62
Red Alsike Clover	1.82	3.33	3.51	3.06
Alfalfa	2.52	.97	1.65	1.67
Artichoke	.07	1.99	3.75	2.55
Tomato	2.80	2.23	2.60	3.43
Cabbage	1.40	1.23	3.04	1.61

TABLE IV.—*Increase or Decrease in Nitrogen Over Increase in Checks. Nitrogen in Milligrams per 10 Grams of Soil. The Minus Sign Indicates Decrease*

TEST SUBSTANCE	AFTER TWO MONTHS	AFTER FOUR MONTHS	AFTER SIX MONTHS
Oat Grass	-.78	-1.43	.51
Sudan Grass	.97	2.08	1.55
Timothy	2.62	1.46	.79
Millet	7.82	-.62	.24
Rye Grass	-.27	3.16	.99
Blue-Grass	.69	2.11	1.35
Broom Sedge	-.15	2.53	1.75
Red Top	1.79	.77	1.28
Tall Oat Grass	1.95	-2.02	-1.72
Sorghum	-.56	1.00	1.06
Wheat	.52	3.69	-.49
Corn	-.61	2.97	.68
Cowpeas	1.86	2.80	.42
Soy Beans	.15	-2.03	1.13
Peas	1.06	2.58	-.26
Hairy Vetch	-.53	-3.22	-.31
Alsike Clover	1.51	1.79	.24
Alfalfa	-1.65	-.97	-.85
Artichoke	1.92	3.38	2.48
Tomato	-.57	-.30	1.03
Cabbage	-.17	.58	.21

TABLE V.—*The Greatest Increase or Decrease in Nitrogen in the Test Substances over the Greatest Increase in Nitrogen in the Check. The Minus Sign Indicates Decrease*

TEST SUBSTANCE	NITROGEN IN 10 GRAMS	NITROGEN IN 300 GRAMS
Oat Grass	.51	15.30
Sudan Grass	1.62	48.60
Timothy	1.00	30.00
Millet	.73	27.90
Rye Grass	2.70	81.00
Blue-Grass	1.65	49.50
Broom Sedge	2.07	62.10
Red Top	1.28	38.40
Tall Oat Grass	-1.72	-51.60
Sorghum	1.06	31.80
Wheat	3.23	96.90
Corn	2.51	75.30
Cowpeas	2.34	70.20
Soybeans	1.13	33.90
Peas	2.12	63.60
Hairy Vetch	-.31	-9.30
Alsike Clover	2.33	69.90
Alfalfa	-.85	-25.50
Artichoke	3.22	96.60
Tomato	1.03	30.90
Cabbage	1.12	33.60

The work was repeated, using sand as a medium, in order to eliminate all possible stimulating influences that might be present in the soil. The sand was first heated in the dry oven and sterilized; the moisture content was adjusted by adding liquid cultures of soil organisms, that had been obtained by inoculating soil into mannite solution[1]. About 54 cc. of this solution were used. The work was then carried out in the same manner as the soil work. It is evident that mannite was added to the soil when it was inoculated with the soil organisms. This solution was used to insure the presence of nitrogen fixing bacteria. The stimulating influence of the plant tissues does not show up as well using sand as a medium as it did using soil.

With many of the substances no stimulating effect was shown; with others a slight stimulating action is shown by the plant tissues.

The increase in total nitrogen in the test substances and in the checks at the different periods is similar to that of the soil. In soil the fixation is usually higher. After the two-month interval there was a decrease in nitrogen in many of the substances. At the end of the four-month period most nitrogen was fixed; at the end of the six-month period there was a falling off in the nitrogen content in all cases.

TABLE VI.—*Total Nitrogen Determination. Each Amount Represents the Average of Two Determinations. Nitrogen in Milligrams per 10 Grams of Sand*

Test Substance	At Beginning	After 2 Months	After 4 Months	After 6 Months
Oat Grass	4.20	5.30	12.13	9.15
Sudan Grass	4.48	4.12	11.82	9.09
Timothy	5.46	7.50	11.15	9.32
Millet	5.81	7.83	11.69	9.96
Rye Grass	7.00	7.14	11.83	8.89
Blue-Grass	5.39	10.88	11.78	9.11
Broom Sedge	4.34	7.21	11.29	8.44
Red Top	4.76	7.66	11.50	8.27
Tall Oat Grass	4.20	9.58	12.30	10.16
Sorghum	5.39	7.98	11.41	8.28
Wheat	4.13	3.52	10.92	8.81
Corn	4.22	8.41	11.34	8.13
Cowpeas	4.90	4.80	13.10	9.93
Soybeans	4.49	4.23	11.76	9.36
Peas	4.21	7.69	11.74	9.13
Hairy Vetch	7.98	9.78	12.58	10.73
Alsike Clover	5.25	4.42	12.33	10.52
Alfalfa	6.03	5.73	13.35	10.68
Artichoke	4.13	10.95	12.57	9.21
Tomato	6.68	11.30	13.42	10.85
Cabbage	5.58	7.65	11.77	8.18
Check	4.02	3.48	10.51	8.43

[1] K_2HPO_4...... .2 gm.
$MgSO_4$....... .2 gm.
NaCl......... .5 gm.
Mannite......20.0 gms.
$FeCl_3$........ 1 drop of 10% solution.
H_2O.........1,000 gms.
Neutralized with 1% KOH.

TABLE VII.—*Increase or Decrease in Nitrogen. Nitrogen in Milligrams per 10 Grams of Sand. Minus Sign Indicates Decrease*

TEST SUBSTANCE	AFTER TWO MONTHS	AFTER FOUR MONTHS	AFTER SIX MONTHS
Oat Grass	1.10	7.93	4.95
Sudan Grass	-.36	7.34	4.61
Timothy	2.04	5.69	3.86
Millet	2.02	5.88	4.15
Rye Grass	.14	4.83	1.89
Blue-Grass	5.49	6.39	3.72
Broom Sedge	2.87	6.95	4.10
Red Top	2.90	6.74	3.51
Tall Oat Grass	4.08	8.10	5.86
Sorghum	2.59	6.02	2.89
Wheat	-.61	6.79	.68
Corn	4.19	7.12	3.91
Cowpeas	-.10	8.20	5.13
Soybeans	-.26	6.27	4.87
Peas	3.48	6.53	4.92
Hairy Vetch	1.82	4.80	2.95
Alsike Clover	-.83	7.08	5.27
Alfalfa	-.30	7.32	4.65
Artichoke	6.82	8.34	5.08
Tomato	4.62	5.74	4.17
Cabbage	2.07	6.19	2.60
Check	-.54	6.49	4.41

TABLE VIII.—*Increase or Decrease in Nitrogen over Checks at Different Intervals. Nitrogen in Milligrams per 10 Grams of Sand. Minus Sign Indicates Decrease*

TEST SUBSTANCE	AT BEGINNING	AFTER 2 MONTHS	AFTER 4 MONTHS	AFTER 6 MONTHS
Oat Grass	.18	1.82	1.62	.72
Sudan Grass	.46	.64	1.31	.66
Timothy	1.42	4.02	.64	.89
Millet	1.79	4.35	1.18	1.53
Rye Grass	3.98	3.66	1.32	.46
Blue-Grass	1.37	7.40	1.27	.68
Broom Sedge	.32	3.73	.78	.01
Red Top	.74	4.18	.99	-.16
Tall Oat Grass	.18	6.10	1.79	1.73
Sorghum	1.37	4.50	.90	-.15
Wheat	.11	.04	.41	.38
Corn	.20	4.93	.83	-.30
Cowpeas	.88	1.32	2.59	1.50
Soybeans	.47	.75	1.25	.93
Peas	.19	4.20	1.23	.70
Hairy Vetch	3.96	6.30	2.07	2.30
Alsike Clover	1.23	.94	1.82	2.09
Alfalfa	2.01	2.25	2.84	2.25
Artichoke	.11	7.47	2.06	.78
Tomato	2.66	7.82	2.91	2.42
Cabbage	1.56	4.17	1.26	-.25

TABLE IX.—*Increase or Decrease in Nitrogen over Increase in Checks Nitrogen in Milligrams per 10 Grams of Sand. Minus Sign Indicates Decrease*

TEST SUBSTANCE	AFTER TWO MONTHS	AFTER FOUR MONTHS	AFTER SIX MONTHS
Oat Grass	1.64	1.44	.54
Sudan Grass	–.18	.85	.20
Timothy	2.58	–.80	–.55
Millet	2.56	–.61	–.26
Rye Grass	.68	–1.66	–2.52
Blue-grass	6.03	–.10	–.69
Broom Sedge	2.41	.46	–.31
Red Top	3.44	.35	–.90
Tall Oat Grass	4.92	1.61	1.45
Sorghum	3.13	–.47	–1.52
Wheat	–.07	.30	–3.73
Corn	4.73	.63	–.50
Cowpeas	–.44	1.71	.42
Soybeans	–.28	–.22	.46
Peas	4.02	.04	.51
Hairy Vetch	2.36	–1.69	–1.46
Alsike Clover	–.29	.59	.86
Alfalfa	.24	.83	.24
Artichoke	7.36	1.85	.67
Tomato	5.16	–.75	–.24
Cabbage	2.61	–.30	–1.81

TABLE X.—*The Greatest Increase or Decrease in Nitrogen in the Test Substances over the Greatest Increase in Nitrogen in the Check. Minus Sign Indicates Decrease*

TEST SUBSTANCE	NITROGEN IN 10 GRAMS OF SAND	NITROGEN IN 300 GRAMS OF SAND
Oat Grass	1.44	43.20
Sudan Grass	.85	25.50
Timothy	–.80	–24.00
Millet	–.61	–18.30
Rye	–1.66	–49.80
Blue-Grass	–.10	–3.00
Broom Sedge	.46	13.80
Red Top	.35	10.50
Tall Oat Grass	1.61	48.30
Sorghum	–.47	–13.10
Wheat	.30	9.00
Corn	.63	18.90
Cowpeas	1.71	51.30
Soybeans	–.22	–6.60
Peas	.04	1.20
Hairy Vetch	–1.69	–50.70
Alsike Clover	.59	17.70
Alfalfa	.83	24.90
Artichoke	1.85	55.50
Tomato	–.75	–22.50
Cabbage	–.30	–9.00

From a comparison of Tables IV and X it is evident that the stimulating effect of the plant tissues is better shown in the soil. Two of the three substances that showed no stimulation with the soil, namely, tall oat grass and alfalfa, showed a stimulating effect with the sand. The other substance, hairy vetch, showed no stimulation in either medium. Nine substances out of the twenty-one failed to show any stimulation to nitrogen fixation in the sand.

This work is, of course, open to experimental error. In the first nitrogen determinations that were run, it was extremely difficult to obtain uniform samples. In the ten grams of soil or sand that were used there should have been one-tenth of a gram of test substance. A little more or less of the tissue makes a big difference in the result. In some cases the nitrogen determinations may be too high, in other cases they may be too low.

Another item that has been mentioned before is that the amount of nitrogen fixed seems to be limited more or less by the amount of nitrogen already present. After nitrogen fixation has proceeded some time, the total nitrogen content in all the substances lies about the same figure. In the soil with one exception, the nitrogen content in milligrams per ten grams lies between 11.73 and 15.03 at the end of two months; between 17.87 and 22.04 at the end of four months and between 18.84 and 22.51 at the end of six months. In the sand the total nitrogen per ten grams lies between 10.92 and 13.42 at the end of four months, and between 9.13 and 10.85 at the end of six months. Again, after a certain degree of nitrogen has been accumulated there is often a decrease in the content. This fact is especially noted in the sand at the end of the six-month interval, where there was a decrease in nitrogen in every case.

The work was carried out in sand with a view to eliminate all stimulating influences of the soil, but it is evident that either a stimulating factor was added with the cultures, or was present in the sand itself. This work is now being repeated in solutions containing a few inorganic salts and no source of carbon save the added plant tissue.

SUMMARY

One percent of various plant tissues was added to Hagerstown silt loam and incubated at 28°C. Total nitrogen determinations were run immediately and then after two, four and six-month intervals. With the exception of three substances out of the twenty-one, a stimulating effect on the part of the plant tissue is definitely shown.

The work was repeated by inoculating sterile sand with cultures obtained from mannite solution and then proceeding as above. The results

obtained here are not comparable to those obtained with the soil. Nine substances of the twenty-one failed to show a stimulating effect and the other twelve showed only a slight stimulation to the fixation of atmospheric nitrogen.

LITERATURE CITED

Haselhoff and Bredemann. 1906. Investigation on Anærobic Nitrogen Collecting Bacteria. Experiment Station. Record 18, 429.

Lipman, J. G. 1908. Azotobacter Studies. N. J. Agr. Exp. Sta. Report for 1908, 138.

Hibbard, P. L. 1910. Notes on the Determination of Nitrogen by the Kjaldahl method. Jour. Ind. and Eng. Chem., 2, 463.

Lipman, C. B., and Burgess. 1915. Studies on Nitrogen Fixation and Azotobacter forms in soils of foreign countries. Centralbl. für Bakt. Abt. II, 40, 481-511.

PART II—A STUDY OF THE BACTERIOLOGY OF FRESH AND DECOMPOSING MANURE[1]

By T. J. Murray

When large amounts of fresh manures are added to a soil rich in nitrates, denitrification sets in and large amounts of plant food are lost. Fred[*] states that "the application of sodium nitrate with fresh horse manure not only causes a loss of the applied nitrate, but it may go on still further destroying the nitrates that may be present in the soil." "Comparisons between fresh and well-rotted manure show a marked increase in favor of the well-rotted manure." It is evident that some change takes place in the rotting process.

This work was carried out with a view to learn something of the bacteriology of fresh and well-decomposed manure and manure in intermediate stages between these two points.

Natural conditions for the fermentation of the manure were obtained by burying a sugar barrel in the manure pit at the experiment station barns. It was filled with manure and surrounded on all sides by manure. The fermentation seemed to proceed very rapidly. After one month the material acquired a rich black color and it retained this color.

Samples of fresh manure were analyzed, and samples of the decomposing manure were analyzed at one-month intervals. In taking a sample, the top layer of manure was removed and the sample was taken from the interior. Then the top layer was replaced. Two five-gram samples were weighed on an analytical balance and then each sample was placed in 495 cubic centimeters of sterile distilled water contained in a one litre Erlenmeyer flask. The manure was broken up by means of a sterile glass rod into small particles. The flask was shaken 15 to 20 minutes and then further dilutions were made from this, 1 to 100 dilution. In spite of this care, the duplicate samples often did not check. The number of bacteria per gram must depend on the amount of straw present. If there is a larger amount of straw present in one sample there will be fewer organisms in that sample.

Bacterial counts were made on Beef Peptone agar, Lipman's synthetic agar and Winogradski nitrogen-poor agar, under aerobic and anaerobic conditions. The number of strict and obligate anaerobes were estimated by streaking a number of colonies from the anaerobic plates and growing these streaked cultures under aerobic conditions. In a similar manner, the

[1]Paper No. 51 from the Laboratories of Plant Pathology and Bacteriology. Virginia Agricultural Experiment Station.

[*]Annual Report of the Va. Agr. Exp. Sta., 1908, p. 149.

number of organisms that would only grow on synthetic and nitrogen-poor media were also obtained.

From a high dilution plate of Beef Peptone agar, one on which there was usually about 100 colonies, all the colonies were picked and inoculated on Beef Peptone agar slants. These organisms were run down and their physiological and staining reactions studied along with their morphology. It is obviously impossible to study all the bacteria in a single gram of manure. With this method an approximation of the flora is obtained. The following media were used:

1. Litmus Milk—good milk with the cream taken off and enough of a one percent solution of azolitmin added to color it.
2. Beef Bouillon—1 percent peptone, .5 percent salt, .3 percent Liebig's Extract of Beef, in distilled water. Reaction+1.5 percent.
3. Beef Peptone Agar—same as No. 2 with 1.5 percent agar-agar.
4. Gelatine—same as No. 2 with 10 percent gelatine, reaction+1.5 percent.
5. Dextrose Bouillon—same as No. 2 with 1 percent dextrose, reaction neutral.
6. Lactose Bouillon—same as No. 2 with 1 percent lactose, reaction neutral.
7. Dunham's Solution—1 percent peptone, .5 percent salt, in distilled water.
8. Lactose-Peptone-Bile—1 percent lactose, 5 percent dried oxgall, 1 percent peptone, in distilled water.
9. Nitrate Solution—.1 percent peptone, .02 percent $K\ NO_3$, in distilled water.
10. Denitrifying Solution—.2 percent $K\ NO_3$, .2 percent $MgSO_4$, .5 percent citric acid, .2 percent K_2HPO_4, .02 percent $CaCl_2$, .425 percent Na_2Co_3, in distilled water.
11. Winogradski—2 percent dextrose, .1 percent K_2HPO_4, .3 percent $MgSo_4$, .0001 percent NaCl, .0001 percent $MnSO_4$, 1 percent $CaCO_3$, 2 drops of 10 percent solution of $FeCl_3$, Agar 1.5 percent in distilled water.
12. Synthetic agar (Lipman and Brown)—1 percent dextrose, .05 percent K_2HPO_4, .02 percent $MgSO_4$, .00005 percent peptone, in distilled water. agar 1.5 percent.

Media numbers 5, 6, 8 and 10 were put in fermentation tubes. All media were sterilized in an autoclave 15 minutes, at 15 lbs, pressure. The media were used for the following purposes:

1. Litmus milk, acid and alkali production, casein coagulated or digested.
2. Beef Bouillon—type of growth.
3. Agar slant—type of growth.
4. Gelatin stab—type of liquefaction or type of growth.
5. Dextrose Bouillon—acid and gas production.
6. Lactose Bouillon—acid and gas production.
7. Dunham's solution—Indol and Ammonia production.

8. Lactose-peptone-bile—gas production.
9. Nitrate solution—nitrite production.
10. Denitrifying solution—production of free nitrogen.

Winogradski, synthetic and beef peptone agars were used for estimating the number of bacteria per gram of manure capable of growing on these media. The cultures were grown at a temperature of 28° C.

TABLE I.—*The Number of Bacteria per Gram at the Different Periods*

Date	Sample Number	Condition	Beef-Peptone Agar	Facultative %	Synthetic Agar	Facultative %	Winogradski Agar	Facultative %
April	No. I	Aerobic	24,000,000		1,330,000		2,450,000	
		Anaerobic	52,000,000		950,000		1,600,000	
April	No. II	Aerobic	1,200,000		170,000		500,000	
		Anaerobic	320,000		130,000		20,000	
April	Average	Aerobic	12,600,000		750,000		1,475,000	
		Anaerobic	26,160,000	98	540,000		810,000	
May	No. I	Aerobic	42,000,000		8,750,000		24,000,000	
		Anaerobic	1,050,000		900,000		790,000	
May	No. II	Aerobic	40,000,000		5,000,000		6,000,000	
		Anaerobic	20,000,000		550,000		630,000	
May	Average	Aerobic	41,000,000		6,875,000	73	15,000,000	80
		Anaerobic	10,525,000	93	725,000		710,000	
June	No. I	Aerobic	17,000,000		1,500,000		3,740,000	
		Anaerobic	1,260,000		660,000		1,820,000	
June	No. II	Aerobic	10,710,000		2,200,000		3,150,000	
		Anaerobic	1,270,000		450,000		940,000	
June	Average	Aerobic	13,855,000		1,850,000	45	3,445,000	80
		Anaerobic	1,265,000	79	555,000		1,380,000	
July	No. I	Aerobic	41.500,000		20,000,000		21,000,000	
		Anaerobic	5,000,000		7,800,000		990,000	
July	No. II	Aerobic	32,500,000		27,000,000		12,000,000	
		Anaerobic	3,000,000		7,000,000		640,000	
July	Average	Aerobic	37,000,000		23,500,000	87	17,500,000	90
		Anaerobic	4,000,000	87	7,400,000		817,000	
August	No. I	Aerobic						
		Anaerobic						
August	No. II	Aerobic						
		Anaerobic						
August	Average	Aerobic				79		70
		Anaerobic		60				
September	No. I	Aerobic	32,000.000		24 000,000		12,000,000	
		Anaerobic	35,000,000		17,200,000		6,700,000	
September	No. II	Aerobic	54 000.000		39.000,000		20.000,000	
		Anaerobic	35,800 000		27,800,000		14,000.000	
September	Average	Aerobic	43.000.000		32.500,000	92	11,000.000	
		Anaerobic	35 400.000	99	22,500,000		10,350.000	
October	No. I	Aerobic	9,000,000		750,000		720,000	
		Anaerobic	980 000		2.000,000		400.000	
October	No. II	Aerobic	26,700,000		7,800,000		500,000	
		Anaerobic	2,150,000		3,500,000		106,000	
October	Average	Aerobic	17.850.000		4.275.000	77	610,000	77
		Anaerobic	1,565,000	100	2,750,000		253,000	

From a perusal of the figures in the foregoing table it is apparent that more bacteria develop on beef peptone agar than on any other medium. For the first four months higher counts were obtained on the nitrogen-poor medium. From that point on, however, higher counts were obtained on synthetic agar.

There are always fewer anaerobes than aerobes with one possible exception—the first month. From 60 to 100 percent of these anaerobes are facultative and grow in the presence of air. From 73 to 92 percent of the organisms that grow on synthetic agar will grow in the presence of nitrogenous organic matter on beef-peptone agar. From 77 to 96 percent of the bacteria that develop on nitrogen-poor media will also grow on beef peptone agar.

A discrepancy often occurs between the bacterial counts of the two samples in the same month. This difference in the count may be explained on the ground, that in one sample there may be more straw than in the other, and hence a lower count because of the increase in weight, due to this straw. The counts vary from 12,000,000 to 43,000,000 organisms per gram of manure on beef peptone agar.

In the following tables, all the organisms from a high dilution plate were picked and determined by running them down through a series of physiological media. Their morphology and relation to the Gram stain was also studied. Organisms with the same reactions were gathered and counted. The name that is given to the organisms is taken from Chester's Manual of Bacteriology, MacMillan, 1902. Very often the descriptions in this manual are meagre and very often do not tally in all respects with the manure organisms. Frequently all the cultural characteristics are not given and the names given to the manure cultures are therefore only an approximation.

TABLE 11. *Description of Bacteria Isolated from Manure*

No	Beef Bouillon	Agar Slant	Potato Slant	Litmus Milk	Gelatin Stab
	April—Eighty-Four Strains of Bacteria Studied				
55	Cloudy with slimy precipitate	Moist filiform	Slimy, yellow to brown pigment	Acid coagulated	-Filiform
23	Cloudy with slimy precipitate	Moist filiform	Slimy, yellow to brown pigment	Acid coagulated	-Filiform
5	Cloudy with slimy precipitate	Moist filiform	Slimy, yellow to brown pigment	Unchanged	-Filiform
1	Cloudy with slimy precipitate	Moist filiform	Slimy, yellow to brown pigment	Acid coagulated	-Filiform
	May—Seventy-Five Strains of Bacteria Studied				
19	Heavy film	Spreading	Wrinkled, reddish-pink no uniformity	Unchanged	-Filiform
18	Heavy film	Spreading	Wrinkled, reddish-pink no uniformity	Acid coagulated	-Filiform
2	Heavy film	Spreading	Wrinkled, reddish-pink no uniformity	Unchanged	-Filiform
2	Heavy film	Spreading	Wrinkled, reddish-pink no uniformity	Unchanged	-Filiform
5	Cloudy with slimy precipitate	Moist filiform	Slimy, yellow to brown pigment	Acid coagulated	-Filiform
6	Cloudy	Filiform	Brown to yellow	Unchanged	-Filiform
6	Heavy film	Pink filiform	Pink	Unchanged	-Filiform
3	Heavy film	Filiform	Brown to yellow	Unchanged	-Filiform
3	Slight turbidity	Filiform	Brown	Unchanged	-Filiform
3	Slight sediment	Filiform	Slight yellow	Acid coagulated	-Filiform
2	Heavy film	Filiform	Brown to yellow	Unchanged	-Filiform
2	Slight turbidity	Filiform	Yellow	Unchanged	-Filiform
2	Heavy film	Filiform	Yellow wrinkled white	Acid coagulated	+Stratiform
1	Heavy film	Filiform	Pink	Acid coagulated	-Filiform
1	Cloudy	Filiform	Pink	Unchanged	-Filiform
	June—Ninety-Two Strains of Bacteria Studied				
20	Red-pink, wrinkled film	Echinulate white, heavy	Heavy, wrinkled red	Alkaline digested	+Stratiform
8	Red-pink, wrinkled film	Echinulate white, heavy	Heavy, wrinkled red	Alkaline digested	+Stratiform
13	Cloudy	Echinulate white, heavy	Heavy, wrinkled white to brown	Alkaline digested	+Stratiform
10	Cloudy	Filiform	Brown	Acid coagulated	-Filiform
9	Cloudy	Filiform	White, wrinkled	Alkaline digested	-Filiform
9	Cloudy	Filiform	White, wrinkled	Unchanged	-Filiform
6	Cloudy and film	Filiform	Wrinkled, brown	Acid coagulated	+Stratiform
4	Cloudy	Filiform	Wrinkled, brown	Acid coagulated	+Stratiform
6	Cloudy	Filiform	Wrinkled, brown	Acid coagulated	+Stratiform
3	Cloudy	Filiform	Wrinkled, brown	Alkaline digested	+Stratiform
2	Cloudy	Filiform	Wrinkled, brown	Acid coagulated	+Stratiform
1	Cloudy, red	Filiform, red	Filiform, slimy red	Acid coagulated	+Cratiform
1	Cloudy	Filiform	Wrinkled, brown	Acid coagulated	+Stratiform

TABLE II—(Continued)

No.	Dextrose Bouillon: Acid	Dextrose Bouillon: Gas	Lactose Bouillon: Acid	Lactose Bouillon: Gas	Bile (gas)	Nitrate Solution (nitrites)	Dunham's: NH₂	Dunham's: Indol	Gram Stain	Name
					April—Eighty-Four Strains of Bacteria Studied					
55	+	+	+	+	+	−	+	+	−short rods	B. coli, p. 205*
23	+	+	+	+	+	−	+	−	−short rods	B. anindoli cum, p. 207
5	+	+	+	+	+	+	+	+	−short rods	B. coli, p. 205
1	+	+	+	+	+	+	+	+	−short rods	B. coli, p. 205
					May—Seventy-Five Strains of Bacteria Studied					
19	−	−	−	−	−	+	+	−	+spore bearing rods	B. vitalis, p. 286
18	−	−	−	−	−	+	+	−	+spore bearing rods	B. vitalis, p. 286
2	−	−	−	−	−	+	+	+	+spore bearing rods	B. vitalis, p. 286
2	+	−	−	−	−	+	+	−	+spore bearing rods	B. vitalis, p. 286
5	+	+	+	+	+	+	+	+	−short rods	B. coli, p. 205
6	+	−	−	−	−	+	+	−	+spore-bearing rods	B. ginglymus, p. 284
6	+	−	−	−	−	+	+	+	−short rods	B. pinatus, p. 217
3	−	−	−	−	−	+	+	+	+spore bearing rods	B. siccus, p. 284
3	+	−	−	−	−	+	+	+	−short rods	B. pinatus, p. 217
3	−	−	−	−	−	−	+	+	−short rods	B. intestinalis, p. 213
2	−	−	−	−	−	−	+	−	+spore-bearing rods	B. ginglymus, p. 284
2	+	−	−	−	−	−	+	−	−cocci	M. cereus, p. 104
2	+	−	−	−	−	−	+	−	−rod	B. dentriticus, p. 248
1	+	−	+	+	−	+	+	+	−rod	B. coli, p. 205
1	−	−	−	−	−	−	+	+	−rod	B. ravenelli, p. 217
					June—Ninety-Two Strains of Bacteria Studied					
20	+	−	−	−	−	+	+	+	+streptobacillus (spores)	Bact. verticillatum, p. 192
8	+	−	−	−	−	+	+	−	+streptobacillus (spores)	Bact. verticillatum, p. 192
13	+	−	−	−	−	+	+	+	+streptobacillus (spores)	Bact. verticillatum, p. 192
10	+	−	−	−	−	+	+	+	−rod	B. pinatus, p. 217
9	+	−	−	−	−	+	+	−	+rod	B. colorabilis, p. 228
9	+	−	−	−	−	+	+	+	+rod	B. colorabilis, p. 228
6	+	−	−	−	−	+	+	+	+rods	B. vulgaris, p. 244
4	+	−	+	−	−	+	+	+	+rods	B. vulgaris, p. 244
6	+	−	−	−	−	+	+	+	−rods	B. hydrophilis, p. 235
3	+	−	−	−	−	−	+	+	−rod	B. hydrophilis, p. 235
2	+	−	−	−	−	−	+	+	−rod	B. hydrophilis, p. 235
1	+	−	+	−	−	+	+	−	−rod	B. prodigiosus, p. 258
1	+	−	−	−	−	+	+	+	+rod	B. vulgaris, p. 244

No.	Beef Bouillon	Agar Slant	Potato Slant	Litmus Milk	Gelatin Stab
	July—Eighty-Six Strains of Bacteria Studied				
19	Very cloudy	Filiform	No visible growth or slight, white	Acid coagulated	–Filiform
8	Very cloudy	Filiform	No visible growth or slight, white	Acid coagulated	–Filiform
8	Very cloudy	Filiform	No visible growth or slight, white	Acid coagulated	+Cratiform
7	Cloudy	Filiform	No visible growth	Unchanged	–Filiform
3	Cloudy	Filiform	No visible growth	Unchanged	–Filiform
5	Film	Echinulate	Heavy white, wrinkled	Acid coagulated	–Filiform
6	Film	Echinulate	Heavy white, wrinkled	Acid coagulated	+Sacculate
5	Film	Filiform and spreading	Heavy red, wrinkled	Acid coagulated	–Filiform
2	Film	Filiform and spreading	Heavy red, wrinkled	Unchanged digested	+Cratiform
5	Film	Filiform	Heavy, wrinkled	Acid coagulated	+Cratiform
2	Film	Filiform	Heavy, wrinkled	Acid coagulated	+Stratiform
2	Film	Filiform	Heavy, wrinkled	Acid coagulated	–Filiform
4	Film	Filiform	Heavy, wrinkled	Acid coagulated	+Stratiform
2	Film	Filiform, yellow	Yellow filiform	Alkaline	+Cratiform
3	Film	Filiform, yellow	Yellow filiform	Unchanged	+Sacculate
2	Film	Filiform, yellow	Yellow filiform	Alkaline	+Cratiform
1	Film	Red, wrinkled growth	Red, wrinkled growth	Alkaline	–Filiform
2	Cloudy	Filiform, moist	Filiform, moist	Acid coagulated	–Filiform
	August—Ninety-Six Strains of Bacteria Studied				
38	Heavy film	Filiform	Heavy, wrinkled brown	Alkaline digested	+Infundibulum and stratiform
21	Heavy film	Filiform	Heavy, wrinkled brown	Alkaline digested	+Infundibulum and stratiform
7	Heavy film	Filiform	Heavy, wrinkled brown	Acid coagulated	+Infundibulum and stratiform
6	Heavy film	Filiform	Heavy, wrinkled brown	Acid coagulated	+Infundibulum and stratiform
4	Heavy film	Filiform	Heavy, wrinkled brown	Unchanged	+Infundibulum and stratiform
3	Heavy film	Filiform	Heavy, wrinkled brown	Unchanged	+Infundibulum and stratiform
2	Heavy film	Filiform	Heavy, wrinkled brown	Unchanged	+Infundibulum and stratiform
10	Cloudy	Filiform	Heavy, wrinkled white to brown	Acid coagulated	+Sacculate
5	Very cloudy	Filiform	Heavy, moist white	Acid coagulated	–Filiform

TABLE 11—(Continued)

No.	Dextrose Bouillon Acid	Dextrose Bouillon Gas	Lactose Bouillon Acid	Lactose Bouillon Gas	Bile (gas)	Nitrate Solution (nitrites)	Dunham's NH_3	Dunham's Indol	Gram Stain	Name
									July—Eighty-Six Strains of Bacteria Studied	
19	+	−	+	−	−	−	+	−	+rod (spores)	B. punctiformis, p. 284
8	+	−	+	−	−	+	+	+	+rod (spores)	B. punctiformis, p. 284
8	+	−	+	−	−	+	+	+	+rod (spores)	B. circulans, p. 279
7	−	−	−	−	−	+	+	+	−rod	B. paradoxus, p. 214
3	−	−	−	−	−	+	+	+	−rod	B. dentriticus, p. 248
5	+	+	+	−	−	−	+	+	+rod	B. muripestifer, p. 227
6	+	−	+	−	−	+	+	+	+rod (spores)	B. mesentericus, p. 272
5	+	−	−	−	−	+	+	+	+streptobacillus	B. vitalis, p. 286
2	+	−	−	−	−	+	+	+	+streptobacillus	B. vitalis, p. 286
5	+	+	+	−	−	+	+	−	+rod	B. vulgaris, p. 244
2	+	+	+	−	−	+	+	+	+rod	B. cloaca, p. 232
2	+	−	+	−	−	+	+	−	+rod	B. colorabilis, p. 228
4	+	−	+	−	−	+	+	+	−rod	B. dentriticus, p. 248
2	+	−	−	−	−	+	+	+	−rod	B. citreus, p. 250
3	+	−	+	−	−	+	+	+	+rod	B. citreus, p. 250
2	+	−	+	−	−	+	+	−	+rod	B. citreus, p. 286
1	−	−	−	−	−	+	+	−	−rod	B. vitalis, p. 280
2	+	−	+	−	−	+	+	−	−rod	B. colorabilis, p. 228
									August—Ninety-Six Strains of Bacteria Studied	
38	−	−	−	−	−	+	+	−	+spore-bearing streptobacillus	B. vulgatus, p. 271
21	−	−	−	−	−	+	+	−	−rod	B. lactius, p. 271
7	−	−	−	−	−	+	+	−	+spore-bearing streptobacillus	B. mesentericus, p. 272
6	−	−	+	+	−	−	+	−	−rod	B. hydrophilis, p. 235
4	+	−	−	−	−	−	+	−	+spore-bearing streptobacillus	B. pamellii, p. 270
3	+	−	+	−	−	+	+	−	+spore-bearing streptobacillus	B. megatherium, Ravenelli, p. 271
2	−	−	+	−	−	+	+	−	+spore-bearing streptobacillus	B. megatherium, Ravenelli, p. 271
10	−	−	−	−	−	−	+	−	−rod	B. hydrophilis, p. 235
5	+	−	+	−	−	−	+	+	−rod	B. intestinalis, p. 213

No.	Beef Bouillon	Agar Slant	Potato Slant	Litmus Milk	Gelatin Stab
		September—Fifty-Seven Strains of Bacteria Studied			
13	Heavy film	Filiform	Moist, white	Alkaline	+Stratiform
12	Heavy film	Filiform	Moist, white	Alkaline	+Stratiform
11	Cloudy	Filiform	Slight growth	Unchanged	–Filiform
11	Slight sediment	Filiform	Slight growth	Unchanged	–Filiform
1	Slight sol. green pigment	Filiform	Slight sol. green pigment	Unchanged sol. green pigment	+Stratiform
4	Heavy film	Echinulate	Moist, yellow to brown	Unchanged	–Filiform
2	Cloudy	Echinulate	Moist, yellow to brown	Unchanged	–Filiform
2	Cloudy	Filiform	Moist, yellow to brown	Unchanged	–Filiform
1	Cloudy	Filiform	Slight growth, filiform yellow	Acid coagulated	–infundibulum
		October—Eighty-One Strains of Bacteria Studied			
30	Cloudy and film	Filiform	Heavy, wrinkled yellow to brown	Alkaline digested	+Stratiform
17	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	+Stratiform
13	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	+Stratiform
5	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	+Stratiform
3	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	–Filiform
2	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	–Filiform
2	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	–Filiform
1	Cloudy and film	Filiform	Heavy, moist white	Alkaline digested	–Filiform
1	Cloudy	Echinulate	Heavy moist, white to brown	Alkaline digested	+Infundibulum
1	Cloudy	Echinulate	Heavy moist, white to brown	Alkaline digested	+Infundibulum
1†	Cloudy	Red pigment	Heavy moist, white to brown	Alkaline digested	+Infundibulum
1	Very cloudy	Echinulate	Slight, moist, white	Acid coagulated	+Sacculate
1	Film	Single large colonies	Very moist, yellow	Alkaline digested	+Napiform
1	Cloudy	Filiform	Slight, white filiform	Alkaline digested	+Infundibulum

TABLE II—(Continued)

No.	Dextrose Bouillon Acid	Dextrose Bouillon Gas	Lactose Bouillon Acid	Lactose Bouillon Gas	Bile (gas)	Nitrate Solution (nitrites)	Dunham's NH$_3$	Dunham's Indol	Gram Stain	Name
September—Fifty-Seven Strains of Bacteria Studied										
13	+	–	–	–	–	–	+	–	+rod (spores)	B. mesentericus, p. 272
12	+	–		–	–	–	+	–	+rod (spores)	B. mesentericus, p. 272
11	+	–	–	–	–	+	+	+	–rod	B. paradoxus, p. 214
11	+	–	–	–	–	+	+	–	+rod	B. shigae, p. 228
1	–	–	–	–	–	–	+	–	+rod	B. pyocyanea, p. 321
4	–	–	–	–	–	+	+	–	–rod	B. ravenelli, p. 217
2	–	–	–	–	–	–	+	+	+spores streptobacillus	B. vitalis, p. 286
2	–	–	–	–	–	+	+	+	–rod	B. paradoxus, p. 214
1	+	–	–	–	–	+	+	–	+spores streptobacillus	B. liodermos, p. 272
October—Eighty-One Strains of Bacteria Studied										
30	–	–	–	–	–	slight +	+	–	+spores streptobacillus	B. vulgatus, p. 271
17	+	–	–	–	–	+	+	+	+spores streptobacillus	B. vulgatus, p. 271
13	–	–	–	–	–	+	+	–	+spores streptobacillus	B. vulgatus, p. 271
5	–	–	–	–	–	–	+	–	+spores streptobacillus	B. vulgatus, p. 271
3	–	–	–	–	–	+	+	–	+spores streptobacillus	B. ginglymus, p. 284
2	–	–	–	–	–	–	+	–	+spores streptobacillus	B. ginglymus, p. 284
2	–	–	–	–	–	+	+	–	–rod	B. ravenelli, p. 217
1	–	–	–	–	–	+	+	–	+cocci	
1	–	–	–	–	–	+	+	–	–rod	B. hydrophilis, p. 235
1	–	–	–	–	–	–	+	–	–rod	B. hydrophilis, p. 235
1*	–	–	–	–	–	+	+	–	–rod	B. prodigiosus, p. 258
1	+	–	+	–	–	–	+	–	+rod (spores)	B. liodermos, p. 272
1	–	–	–	–	–	–	+	–	–rod	B. hydrophilis, p. 235
1	+	–	–	–	–	+	+	–	–rod	B. hydrophilis, p. 235

† Refers to the page in Chester's Manual of Determinate Bacteriology, MacMillan, 1902 which gives description of the bacteria named

* Bacterium formed red pigment throughout on all media

In April, 84 bacteria were isolated and run down. Fifty-five, or 65.5 percent gave all the reactions of B. coli. Twenty-three or 27.4 percent others agree in all respects but do not produce indol-B. anindolicum. Five others agreed in all respects with B. coli except that no acid was formed in milk. Only one failed to form gas in lactose peptone bile. It is quite evident that all these organisms are members of the colon group of intestinal bacteria.

In May, after the fermentation had gone on one month, 75 cultures of bacteria were worked with. Six only, or 8 percent showed the cultural characteristics of B. coli. Forty-one or 54.6 percent had reactions very similar to B. vitalis and constitute the first four groups in the table. Eleven or 14.6 percent of the remaining are also gram positive spore formers. There were two gram negative cocci present, the rest, twenty-one in number, or 28 percent, were gram negative rods. The gram positive spore-forming strepto-bacilli predominate.

In June, 92 bacteria were isolated. B. coli this month is entirely missing. It does not appear again throughout the work. The first three groups in the table constitute forty-one or 44.5 percent resemble Bact. verticillatum, a gram positive spore-bearing strepto-bacterium. The rest of the organisms are broken up into a variety of non-spore forming bacilli.

In July, the predominating type is not clearly marked. Only twenty-six, or 30 percent of the eighty-seven bacteria isolated belong to this class, B. punctiformis—a gram positive spore former. Fifteen other organisms, 18.4 percent are also sporé formers. The rest of the bacteria are a variety of non-spore bearing bacilli.

In August, the potato group of spore forming strepto-bacilli predominate, B. vulgatus is the predominating group. Thirty-eight, or 39.5 percent out of the ninety-six bacteria isolated belong to this group. Twenty-seven other bacteria had characters similar but were gram negative and the spore formation could not be determined. Besides these, nine others or 9.3 percent were spore forming strepto-bacilli of the same group. The remaining fifteen cultures of bacteria were gram negative bacilli.

In September, B. mesentericus was the predominating type. Twenty-five, about 44 percent of the fifty-seven cultures of bacteria belong to this group. Three other cultures are also spore bearing gram positive bacilli. The remainder of the cultures were non-spore bearing bacilli.

In the last month, October, sixty-five or 80 percent of the eighty-one bacteria studied resembled B. vulgatus, a gram positive strepto-bacillus. Eight others, 9.8 percent were also gram positive strepto-bacilli. There was one gram positive coccus present and the rest were gram negative bacilli.

TABLE III.—*Biochemical Activities of the Bacteria Isolated from Manure*

Substance Attacked	April 84		May 75		June 92		July 86		Aug. 96		Sept. 57		Oct. 81		Type of Bacteria
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Gelatin, not liquefied	84	100	73	97.3	28	30.4	49	56.9	10	10.4	30	52.6	10	12.3	Non-proteolytic
Gelatin, liquefied	.....	.....	2	2.7	64	69.6	37	43.1	86	89.6	27	47.4	71	87.7	Proteolytic
Milk, acid coagulated	79	94	29	38.6	30	32.6	66	76.7	28	29.1	1	1.7	1	1.2	Non-proteolytic
Milk, alkaline digested	.....	.....	.....	.....	53	57.6	5	5.8	59	61.4	25	43.8	80	98.7	Proteolytic
Milk, unchanged	5	6	46	61.3	9	9.7	15	17.4	9	9.3	31	54.3	.....	.....	Neutral
Peptone, ammonia formed	84	100	75	100	92	100	86	100	96	100	57	100	81	100	Ammonifiers
Nitrates, nitrites formed	84	100	67	87.3	87	94.5	63	73.2	71	73.9	29	50.8	41	50.6	Denitrifying bacteria of the nitrite type
Nitrates, free nitrogen formed	2	2.3	13	17.3	8	8.6	.....	.....	4	4.2	5	8.7	2	2.4	Denitrifying bacteria
Peptone, indol formed	61	72.6	26	34.6	74	80.4	58	67.4	5	5.2	15	26.3	13	15.9	
Gram stain, gram negative	84	100.	21	28	22	20.6	17	19.6	41	42.7	17	29.8	7	8.7	

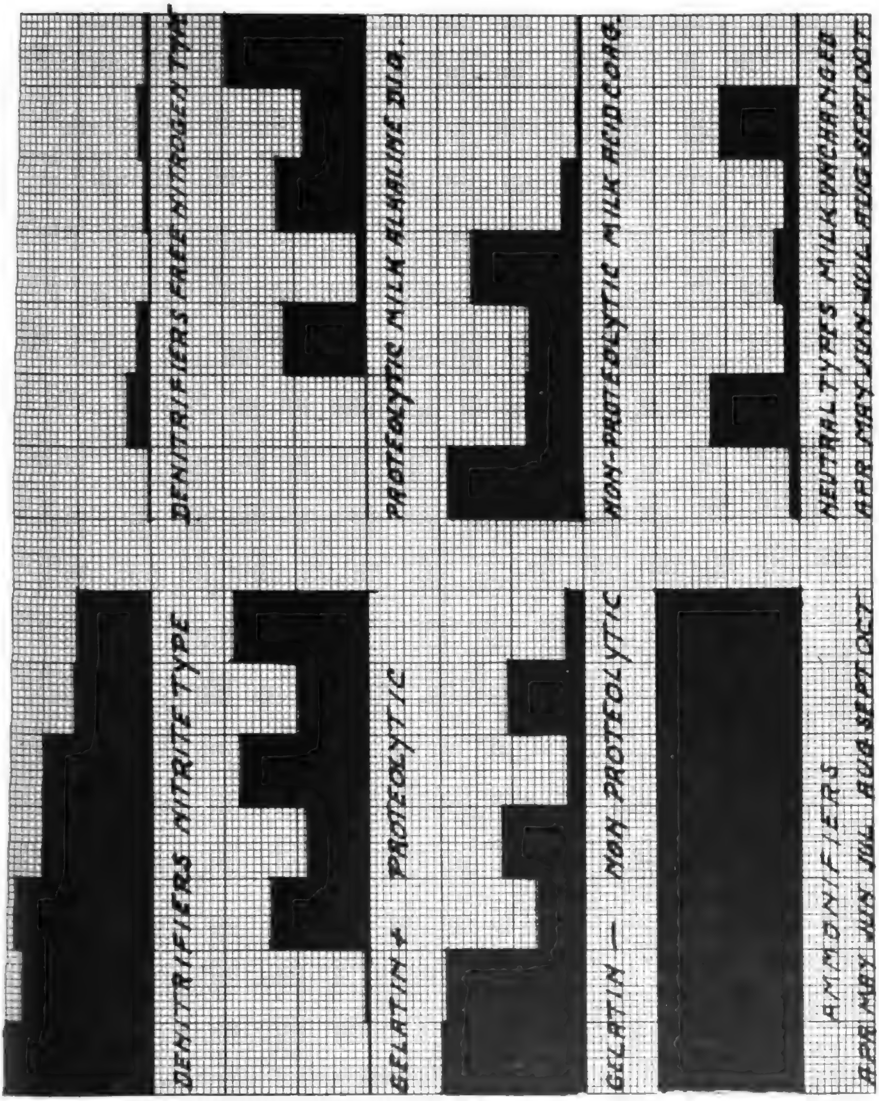


PLATE I—Types of Bacteria at the different intervals

In the circulation of nitrogen in nature several distinct processes take place. If we start with the protein material this is finally changed to ammonia compounds and the whole process is included under the term ammonification. The ammonia compounds are oxidized to nitrites and then to nitrates, in which form they are utilized by plants, and this process is termed nitrification. At times the reverse of this last process takes place. If nitrates are reduced to nitrites or finally to free nitrogen this is known

as denitrification. Micro-organisms carry out all these activities. Probably the most complicated of the foregoing is ammonification. The protein molecule* is complex and by the activities of bacteria it is broken down into proteoses and then into peptones. This is peptonization. These substances are broken down into polypeptids and amino acids and finally to ammonia. The successive cleavages of protein materials is termed proteolysis. Organisms carrying out this process may be designated as proteolytic bacteria.

Proteolytic bacteria are practically missing for the first two periods. Then they gain ascendency over the non-proteolytic types. At the July period the non proteolytic types are slightly higher than proteolytic types. From this time on the proteolytic types predominate. In the last month there are practically none of the non-proteolytic types left.

Denitrifying bacteria were also present throughout the period of the experiments. The type that forms nitrites from nitrates fell off continuously from 100 percent in the first month to 50 percent in the last month. Denitrifying bacteria that form free nitrogen from nitrates were also present throughout with one exception. They were always in the minority. The largest numbers were present during the second month when 17 percent of the organisms gave free nitrogen from potassium nitrate.

SUMMARY

Samples were taken first of fresh and then decomposing manure at monthly intervals for a period of six months. The samples were plated on beef peptone agar, synthetic agar and nitrogen-poor agar under aerobic and anaerobic conditions. The number of bacteria per gram was estimated on these media under these conditions. The percentage of facultative anaerobes was estimated by growing several cultures from the anaerobic plates under aerobic conditions. The percentage of organisms facultative in regard to nitrogen poor and synthetic media was also estimated. From a high dilution plate of beef peptone agar, one on which there was approximately 100 colonies, all the bacteria were picked and inoculated on agar slants. These cultures were stained by the Gram method and run down through a series of physiological culture media; their chemical activities were studied and the organisms identified. The following things were noted throughout this work.

1. Higher counts were obtained on beef peptone agar than on any other media. For the first four periods higher counts were obtained on

*Buchanan's Household Bacteriology, MacMillan, 1913, p. 179.

Winogradski nitrogen-poor media. Thereafter higher counts were obtained on synthetic media.

2. Anywhere from 12 to 43 million organisms per gram were found on beef peptone agar. There is no progressive increase or decrease throughout the six months.

3. There is always, with one possible exception, the first month, more aerobes than anaerobes. The anaerobic count on beef peptone agar varied from 1,265,000 to 35,400,000 bacteria per gram.

4. From 60 to 100 percent of the anaerobes on beef peptone agar were facultative in regard to air. 73 to 92 percent of the bacteria that developed on synthetic agar were facultative in regard to beef peptone agar.

From 77 to 96 percent of the bacteria that developed on Winogradski nitrogen-poor media, were facultative in regard to beef peptone agar.

5. In the first month before any fermentation had taken place 65.5 percent of the organisms isolated and studied were B. coli. The remainder were very closely related. During the second month B. coli was present to the extent of eight percent. Thereafter it was entirely missing.

6. After one month there is always a predominating type of bacterium, usually a gram positive spore forming, strepto-bacillus. Usually there are more spore forming bacteria than non-spore forming organisms present.

7. Ammonifying organisms are present throughout all the work. Every organism isolated formed ammonia from peptone.

8. For the first two periods proteolytic bacteria are practically missing. Thereafter, there is a progressive increase and during the last month, practically all the bacteria are of this type.

9. Denitrifying bacteria of two types are present, those that form nitrites from nitrates and those that form free nitrogen from nitrites.

The type that forms nitrites from nitrates is present throughout. There is a progressive decrease from 100 percent in the fresh manure to 50 percent in the last sample of decomposed manure.

The other type is present, with one exception, throughout. These organisms that give off free nitrogen are always in the minority, although in the period one month after the fermentation had started there was as many as seventeen percent present.

POT EXPERIMENTS TO DETERMINE PRIMARILY THE AVAILABILITY OF PHOSPHORIC ACID IN THOMAS SLAG PHOSPHATES IN COMPARISON WITH OTHER PHOSPHATES

By W. B. ELLETT AND A. A. INGHAM*

This work was outlined by the Thomas Slag Phosphate Committee of the Association of Official Agricultural Chemists.

The object of these experiments was to determine primarily the availability of phosphoric acid in Thomas slag phosphates, measuring availability by a comparison between the yields secured where four such phosphates were used, and those obtained from the use of ground blue phosphate rock, acid phosphate, sodium phosphate, and double superphosphate. The experiments were conducted in two series of pots, one remaining fallow previous to the application of the fertilizers, the other growing a crop of soy beans to be turned under as green manure at the time of adding the fertilizing materials, thus affording opportunity to study the effects of this green manure on the availability of the various phosphatic materials.

As no field work was undertaken in connection with the pot work, we were not restricted in securing soil for the experiment, and we selected a type of soil known as the Red Pulaski Shale. This type of soil occurs in the lower Carboniferous strata, overlying the Price sandstone. Due to its relatively great thickness with respect to its restricted area, and lack of salt-water fossils, it is supposed to represent delta deposits, previous to the encroachment of the sea in which was laid down the overlying marine Greenbrier limestone. The outcrops of the shale occur in the vicinity of faults, the principal ones being found at the foot of the southeastern slopes of Brush Mountain in Montgomery County, Virginia, Cloyd and Walker Mountains in Pulaski County, Virginia, and surrounding Price Mountain in Montgomery County. Further to the southwest, the same formation is called the Maccrady shale. The Pulaski shale, on weathering, gives a dull red soil of very fine texture. The soil for these experiments was taken from a worn out field on the north side of Price Mountain, about two miles southwest of Blacksburg. This soil was known to be deficient in phosphoric acid on account of its failure to produce crops unless phosphoric acid was added; and this deficiency was also indicated by chemical analyses.

Soil to the depth of about seven inches, excluding any undecomposed organic material and stones was taken. A sample of the soil, as weighed

*Died June 18, 1917.

into the pots, was secured and the following determinations made:

1. Loss upon air drying.

Weight of sample before air drying	3684 grams
Weight of sample after air drying	3219 grams
Loss on drying,	465 grams, or 12.62% moisture.

2. Percent of coarse material that did not pass through a 3 mm. sieve.

Sample used	3219 grams
Portion of sample which did not pass through 3 mm. sieve	537 grams
Portion of sample which did not pass through 1 mm. sieve	567 grams
Portion of sample which did pass through 1 mm. sieve	2115 grams

Therefore, 83.32 percent of the oven dried sample passed through the 3 mm. sieve and 78.86 percent of the soil which passed through the 3 mm. sieve also passed through the 1 mm. sieve.

3. Percent of moisture.

On air drying	12.62
On heating air-dried sample in oven	.96
Total moisture	13.58

4. Chemical analysis, using hydrochloric acid (specific gravity, 1.115).

Insoluble matter	87.07
Potash (K_2O)	.43
Soda (Na_2O)	.17
Lime (CaO)	.03
Magnesia (MgO)	.04
Manganese oxide (MnO)	trace
Ferric oxide (Fe_2O_3)	.20
Alumina (Al_2O_3)	7.61
Phosphoric acid (P_2O_5)	.06
Sulfuric acid (SO_3)	.32
Water and organic matter	4.36
Total	100.29
Nitrogen in soil	.058

According to the foregoing method of analysis, and according to Hilgard's conclusions, this soil is deficient in nitrogen, lime, and phosphoric acid, while the amount of potash probably is sufficient.

Equal quantities of soil by weight were placed in each pot, and when the soil settled, its surface reached within an inch of the top. No subsoil was used, as the pots were not deep enough to require it. The weight of soil added to each pot was 8000 grams, an equivalent of 6989.4 grams of air dry soil. The diameter of the pots was 8.5 inches, giving each pot a surface area of 56.75 square inches. The depth of the pots was 8.5 inches.

The experiments were conducted in two main divisions. In the first division, soy beans were grown without fertilization (except lime), the fertilizer being applied subsequently in intimate contact with the green crop after the green crop had been cut up and was ready to be mixed with the soil in the respective pots. In the second division the soil in the pots remained in a fallow condition, after the application of lime, during the growth of the soy beans in the other division. Each division was run in duplicate, except pots 9, 21 and 22 which were repeated three times. Pots 294 and 260 were run, receiving no treatment whatever, except the non-leguminous crops were grown in them. Pots 291 and 292 were used as checks on the above two pots, receiving the same treatment, and in addition, growing the legume crop. The arrangement of the pots in the greenhouse was as follows:

Division 1.—Legume Crop. Pots 1 to 22 inclusive, with all pots duplicated except pots 9, 21 and 22, which were repeated three times. Pots 291 and 292 were used as checks.

Division 2.—Fallow. Pots 1 to 22 inclusive, with all pots duplicated except pots 9, 21 and 22, which were repeated three times. Pots 294 and 260 were used as checks.

After the addition of the soil to the pots, lime was added on the basis of analysis obtained by the Veitch method. According to the analyses made by this method the soil was found to require 13.63 grams of CaO, or 24.3 grams of $CaCO_3$, per 6989.4 grams of air-dried soil.

The phosphatic fertilizing materials, together with the analyses of the same, were furnished by the Thomas Slag Phosphate Committee of the Association of Official Agricultural Chemists, and are as follows:

The Phosphatic Fertilizing Materials
The Treatment for the Twenty-Two Pots Are as Follows

Materials	Fineness: Percentage Through a Sieve: Round-Holed 1 mm.	½ mm.	Square-Holed ¼ mm.	$\frac{1}{10}$ mm.	Percentage of Phosphoric Acid: Total	Available*	Moisture
Slag A	99.86	99.31	97.28	65.36	18.06	15.87	.19
Slag B	99.81	98.42	95.01	73.17	17.84	14.74	.29
Slag C	99.52	98.14	94.14	68.43	13.03	13.25	.28
Slag D	99.16	96.50	91.10	67.34	15.57	14.98	.30
Phosphate rock	99.65	99.45	95.80	72.82	29.40	......	......
Acid phosphate	......	......	......	......	19.49	17.82	......
Sodium phosphate	......	......	......	......	20.87	20.87	......
Double super-phosphate	......	......	......	......	46.25	46.02	......

*Available phosphoric acid determined in slags by Wagner's two percent citric acid method, and in other materials indicated by the official ammonium citrate method.

The analyses, as furnished, were the basis on which the calculations for the addition of these materials were made. The lime added to the pots was chemically-pure $CaCO_3$, while the non-phosphatic fertilizers were added from the sources and in the same proportions as prescribed in the unit applications given below.

Unit Fertilizer Applications

N—0.06% nitrogen from dried blood, and 0.01% from Nitrate of Soda.
K—0.10% P_2O_5 from low grade sulphate of potash.
P—0.14% P_2O_5 respectively from the different phosphatic materials indicated.
L—0.10% $CaCO_3$ in addition to that required by Vetch test.
Lx—0.15% $CaCO_3$ in addition to that required by Vetch test.

All fertilizers were applied according to calculations based on the above unit applications, and the analyses of the various materials to be applied to the pots.

As mentioned above, the experiment was divided into two main divisions. Each division was run in duplicate, thereby giving two series to a division. These series were made up of 22 pots, with all pots in the two main divisions bearing the same number receiving the same fertilizer

treatment, regardless of the cropping treatment. The treatments for the 22 pots are as follows:

Pot	Phosphoric Acid from	Pot	Phosphoric Acid from
1—NKL	None	12—NPKL	Slag C
2—NKL	None	13—NPKL	Slag D
3—N(P½)KL	Slag A	14—NPKL	acid phosphate
4—N(P½)KL	Slag B	15—NPKL	ground (blue) phosphate rock
5—N(P½)KL	Slag C	16—NPKL	sodium phosphate
6—N(P½)KL	Slag D	17—NPKLx	sodium phosphate
7—N(P½)KL	acid phosphate	18—(N1½)P(K1½)L	sodium phosphate
8—N(P½)KL	ground (blue phosphate rock	19—N(P1½)KL	sodium phosphate
9—N(P½)KL	sodium phosphate	20—N(P2)KL	ground (blue) " rock
10—NPKL	Slag A	21—N(P½)KL	double superphosphate
11—NPKL	Slag B	22—NPKL	double superphosphate

On May 3rd, 1915, all the pots, except checks 291, 292, 294 and 260 were limed according to the requirements determined by the Veitch test. All pots in the first division, and also checks 291 and 292 were planted with Haberlandt soy beans on May 4th. An effort was made to retain the same number of plants in each pot, and this number varied from 6 to 8. The bean crop was allowed to grow until July 27th, at which time pods had begun to form on the plants. The stand was uniform throughout. On this latter date the crop was removed from each pot, cut up finely with shears, and mixed in a tub with the soil in which it grew along with the fertilizer required for that particular pot. On the same date, the soil in the pots that had remained fallow during the growth of the legume in the other division was mixed with the required fertilizers and returned to the pots. All pots were then allowed to remain fallow two weeks before planting.

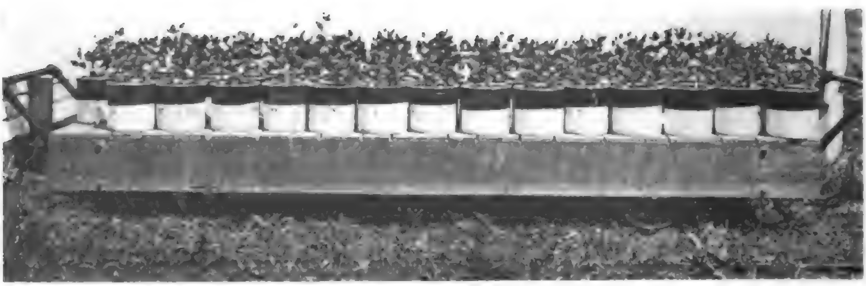


Fig. 1—View of Division 1, with legume crop

On August 11, all pots were sown with millet, enough seed being used to insure a good stand. The plants were thinned to leave 14 to the pot, and with a few exceptions this number remained the same at harvest. The watering of the plants was left to the judgment of the grower, suf-

ficient water being applied to satisfy the needs of the plants. The crop was harvested on October 25th, a record being kept of the number of plants in each pot, stage of maturity, and dry weight of the crop of each pot. The plants from each pot were placed in a paper bag and dried in a steam-heated drying closet. These results are set forth in table 1.

TABLE I.—*Millet Crop; the Averages for Pots of Same Treatment*

Pot No.	Average Dry Weight in Grams		Fertilizer Treatment
	Series 1 and 2	Series 3 and 4	
	Grams	*Grams*	
1	1.25	.2	NKL
2	1.1	.16-	NKL
3	10	15.5	N(P½)KL Slag A
4	19.1	22.35	N(P½)KL Slag B
5	20.75	18	N(P½)KL Slag C
6	16.8	*	N(P½)KL Slag D
7	25.25	21.8	N(P½)KL acid phosphate
8	2.95	.75	N(P½)KL ground phosphate rock
9	32.9	41.9	N(P½)KL sodium phosphate
10	21.55	26.3	NPKL Slag A
11	24.65	32.55	NPKL Slag B
12	20.8	31.45	NPKL Slag C
13	22.9	22.9	NPKL Slag D
14	33.9	45.85	NPKL acid phosphate
15	1.8	1	NPKL ground phosphate rock
16	32.05	45.8	NPKL sodium phosphate
17	34.1	40.55	NPKLx sodium phosphate
18	36.85	37.3	(N1½)P(K1½)L sodium phosphate
19	43.8	43.75	N(P1½)KL
20	2.9	1.2	N(P½)KL ground phosphate rock
21	*	34.9	N(P½)KL double superphosphate
22	31.7	44.5	NPKL double superphosphate
		Checks. Legume	
291, 292	2.5		No fertilizer or lime
		Checks. Fallow	
294, 260	.63		No fertilizer or lime

*All restuls thrown out.

Between December 10th and 20th, the soil in each pot was well trowelled, and watered. On January 3rd, 1916, all pots were sown to barley. Sufficient seed was used to insure a good stand. Later the plants were thinned leaving 12 in each pot, which number, with few exceptions was present when harvested. The crop was harvested on April 14th, 1916, and a record kept of the number of plants to the pot, stage of maturity, main heads, tiller heads, and dry weight of each individual crop. This record is given in table 2. No additional fertilizers was supplied to the soil in these pots for the barley plants.

TABLE II.—*Barley Crop; the Averages for Pots of Same Treatment*

POT NO.	AVERAGE DRY WEIGHT OF CROP ON SERIES 1 AND 2	AVERAGE DRY WEIGHT OF CROP ON SERIES 3 AND 4
	Grams	*Grams*
1	11.6	11.9
2	11.6	7.2
3	46.0	42.1
4	34.5	36.2
5	36.2	37.9
6	32.2	36.0
7	36.8	38.4
8	11.9	12.0
9	43.8	38.9
10	40.4	50.1
11	44.3	43.0
12	50.4	49.5
13	41.8	52.7
14	42.2	46.9
15	15.2	10.2
16	52.3	46.2
17	51.0	49.7
18	54.9	60.5
19	50.5	47.6
20	16.7	15.3
21	37.1	38.3
22	41.7	38.3

TABLE III.—*Total Weight of Millet and Barley for Same Treatment*

POT No.	SUM OF MILLET AND BARLEY—AVERAGES ON DIVISION 1 (Series 1 and 2)	DIVISION 2 (Series 3 and 4)	FERTILIZER TREATMENT
	Grams	*Grams*	
1	12.85	12.1	NKL
2	12.7	7.36	NKL
3	56	57.6	N(P½)KL Slag A
4	53.6	58.55	N(P½)KL Slag B
5	56.95	55.9	N(P½)KL Slag C
6	49	43.6	N(P½)KL Slag D
7	62.05	60.2	N(P½)KL acid phosphate
8	14.85	12.75	N(P½)KL ground phosphate rock
9	76.7	81.8	N(P½)KL sodium phosphate
10	61.95	76.4	NPKL Slag A
11	68.95	75.55	NPKL Slag B
12	71.2	80.95	NPKL Slag C
13	64.7	75.6	NPKL Slag D
14	76.1	92.75	NPKL acid phosphate
15	17	11.2	NPKL ground phosphate rock
16	84.35	92	NPKL sodium phosphate
17	85.1	90.25	NPKLx sodium phosphate
18	91.75	97.8	(N1½)P(K1½)L sodium phosphate
19	94.3	91.35	N(P1½)KL sodium phosphate
20	19.6	16.5	N(P2)KL ground phosphate rock
21	74.2	73.2	N(P½)KL double superphosphate
22	73.4	76.8	NPKL double superphosphate

Checks. Legume

291 } 292 }		2.5	No fertilizer or lime

Checks. Fallow

294 } 260 }		.63	No fertilizer or lime

The discussion of the results obtained in this experiment are based on table 3, which gives the sums of the averages of the two crops grown on pots with the same fertilizer treatment. A discussion of Table 1 would probable include erroneous conclusions as the results in Table 2, in some instances, would not bear out the former deductions. For example, compare treatment 3 in Tables 1 and 2. In the first case the crop from this treatment is the lowest obtained from the four slags in Pots 3, 4, 5, and 6, while in the latter case it is the highest. This result is probably explained by some condition of the environment of the first crop which prevented it from securing the full benefit from the fertilizers. Consequently, a larger amount than would be expected was left for the second crop, which made use of it in the production of a larger yield. Therefore, when we add the average weights of the two crops for the same treatment these inequalities will be eliminated to a large extent, and our conclusions will be more trustworthy.

One of the first things that is apparent in Table 3 is the value of the soil selected for this work with various phosphatic materials. It was not only deficient in phosphoric acid but also in nitrogen and lime. In the check pots, the limiting factor was either nitrogen, potash or lime, as seen by a comparison of the checks with Pots 1 and 2. The latter had an abundance of plant food with the exception of phosphoric acid, as the amount of phosphoric acid present was the same as that found in the original soil.

The nitrogen and potash were always applied in the same proportion, and their effects are discussed together. It is observed that the unit treatment of these two elements was sufficient in all cases to make phosphoric acid the limiting factor. In Pot 18, where these two elements are applied at the rate of one and one-half times unity, a small increase is noticed, but this is only slightly above Pots 17 and 18, and is not sufficient to prove that the increase was due to the additional nitrogen and potash.

As regards the effect of lime, the initial treatment, as determined by the Veitch method, was sufficient and insured that it would not influence the growth of the plants, regardless of the presence or absence of other

elements of plant food. In Pot 17, the use of an additional amount of lime gave no extra effect whatever.

The phosphatic materials will be taken up in the order of their availability, as proved by the yields produced, beginning with the least available, or ground phosphate rock (floats). This form of phosphorus gave very little, if any, increase over pots 1 and 2 to which no phosphorus had been added, whether the ground phosphate rock was added at the rate of P½, P, or P2. Nor did the legume crop in Division 1 seem to make the floats any more available. The pots in which the legume was grown, consistently produced a slight excess over those that had remained fallow, yet when the increase observed in the check legume over the check non-legume is subtracted from this excess and the increased amount of floats added to pot 20 is considered, only a very small amount, if any at all, can be attributed to the influence of the legume on the ground phosphate rock. This result may be due to the absence of sufficient organic matter to make its presence felt. It is true that the original soil was deficient in organic material, but the legume crop turned under was not a small one by any means. With approximately 8 plants per pot, a surface area of 7.5 square inches is given to each plant.

Of the four slags used, all are about equal in their availability, but Slag C appears to be the most available, and Slag D is the least available. Slag D gives the lowest yield when applied at the rate of P½, but when applied at the rate of unity, or P, sufficient phosphorus is probably present to secure the maximum crop. When applied at the rate of P½, the yield from the legume and non-legume pots is nearly equal. However, when applied at the rate P, the fallow pots show the largest yield.

The next phosphatic material in order of availability is acid phosphate. When applied at the rate of P½, along with NKL the phosphoric acid is the limiting factor, and the availability of the acid phosphate is slightly above that of the slags, and below that of double superphosphate and sodium phosphate, applied at the same rate. When applied at the rate P, it is still more available than any of the slags; its availability exceeds that of double superphosphate, and equals that of sodium phosphate applied at the same rate.

The double superphosphate, at the rate P½, produced a greater crop than any of the slags or acid phosphate, applied at the same rate, but fell below the yield produced from an equal amount of phosphorus in the form of sodium phosphate. When added at the rate P, the superphosphate did not give an increased yield over the rate P½, showing that with this fertilizing material a smaller application than P½ could have been added.

Sodium phosphate proved to carry the most available phosphoric acid. The treatment P gave a slightly greater crop than P½; and increasing the N or K, or the amount of P, separately, did not increase the yield.

Table 4 gives the relative availability of the phosphatic materials,

TABLE IV.—*Percentage of Availability of Phosphatic Fertilizers*
One-Half Unit Application
Unit Application

Pot No.	Percent Availability with Legume Turned Under	Percent Availability with Fallow	Fertilizer
		ONE-HALF UNIT APPLICATION	
			P½ from
3	90.25	95.68	Slag A
4	86.38	97.25	Slag B
5	91.78	92.86	Slag C
6	78.97	72.42	Slag D
7	100.00	100.00	acid phosphate
8	23.90	21.18	ground phosphate rock
9	123.61	135.88	sodium phosphate
21	119.58	121.59	double superphosphate
		UNIT APPLICATION	
			P from
10	81.41	82.37	Slag A
11	90.60	81.46	Slag B
12	93.56	87.28	Slag C
13	85.02	81.51	Slag D
14	100.00	100.00	acid phosphate
15	22.34	12.08	ground phosphate rock
16	110.84	99.19	sodium phosphate
22	96.45	82.80	double superphosphate

taking the yield produced by a ½-unit application of acid phosphate as 100 percent and comparing the yield produced by a ½-unit application of the other phosphatic fertilizers. Again, applications of unit quantities were the basis of a second set of calculated availabilities.

The following photographs will give an accurate view of the appearance of the two crops, the pots in which they were grown, their maturity and relative size. In arranging the pots to be photographed, particular care was taken to avoid using extremes, so that any contrasts that can be seen are as near as possible to the average. The treatments of the respective pots are given below the photographs.

(The authors wish to acknowledge the co-operation and assistance received from Mr. W. G. Harris and Dr. A. W. Drinkard, Jr. Mr. Harris

set up and limed the soil in the pots, sowed the legume crop in Division 1, and made analyses 1, 2, and 3 on page 119. The photographs were taken by Dr. Drinkard).

CONCLUSIONS

The soil used for these experiments was deficient in nitrogen, lime and phosphorus in available forms.

A comparison of the availabilities of the various phosphatic materials, as measured by crop yields was made. The availability of the four slag phosphates was about equal. Slag D, however, appeared to be the least available, which may be accounted for by its being slightly coarser than the other three, as shown by the percentages secured by mechanical analysis.

As regards the slag phosphate no correlation is shown between the crop yield and the percentages of available phosphoric acid obtained by the 2 percent citric acid method of analysis.

When sodium phosphate, double super-phosphate, and acid phosphate are compared, their availabilities are seen to fall in the order named, which agrees with the analyses secured by the official ammonium citrate method.

Where ground phosphate rock (floats) was used the crop yields obtained indicate that this material is of very little value in furnishing phosphoric acid on this soil type. No appreciable increase in the availability of this material was shown by the turning under of a legume crop.

PLATE 1.—*Green Manure Added*

POT

1—NKL, no phosphorus.

3—N(P½)KL, phosphoric acid from Slag A.

4—N(P½)KL, phosphoric acid from Slag B.

5—N(P½)KL, phosphoric acid from Slag C.

6—N(P½)KL, phosphoric acid from Slag D.

7—N(P½)KL, phosphoric acid from acid phosphate.

8—N(P½)KL, phosphoric acid from ground (blue) phosphate rock.

9—N(P½)KL, phosphoric acid from sodium phosphate.

NOTE—Plants in the upper tier of pots are barley; those in the lower tier are millet. This applies to plates I to VIII inclusive.

PLATE 2.—*Fallow; No Green Manure Added*

POT

1—NKL, no phosphorus.
3—N(P½)KL, phosphoric acid from Slag A.
4—N(P½)KL, phosphoric acid from Slag B.
5—N(P½)KL, phosphoric acid from Slag C.
6—N(P½)KL, phosphoric acid from Slag D.
7—N(P½)KL, phosphoric acid from acid phosphate.
8—N(P½)KL, phosphoric acid from ground (blue) phosphate rock.
9—N(P½)KL, phosphoric acid from sodium phosphate.

PLATE 3.—*Green Manure Added*

POT
1—NKL, no phosphorus.
10—NPKL, phosphoric acid from Slag A.
11—NPKL, phosphoric acid from Slag B.
12—NPKL, phosphoric acid from Slag C.
13—NPKL, phosphoric acid from Slag D.
14—NPKL, phosphoric acid from acid phosphate.
15—NPKL, phosphoric acid from ground (blue) phosphate rock.
16—NPKL, phosphoric acid from sodium phosphate.

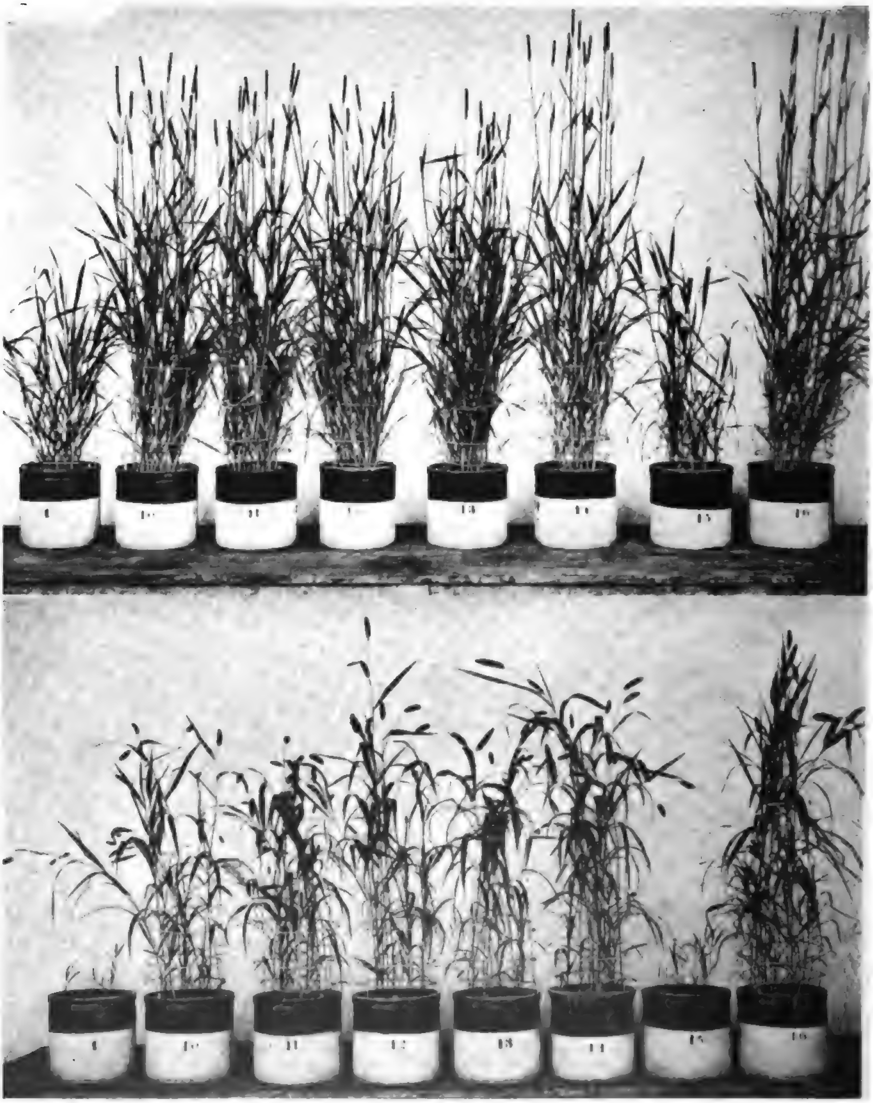


PLATE 4.—*Fallow; no Green Manure Added*

POT
1—NKL, no phosphorus.
10—NPKL, phosphoric acid from Slag A.
11—NPKL, phosphoric acid from Slag B.
12—NPKL, phosphoric acid from Slag C.
13—NPKL, phosphoric acid from Slag D.
14—NPKL, phosphoric acid from acid phosphate.
15—NPKL, phosphoric acid from ground (blue) phosphate rock.
16—NPKL, phosphoric acid from sodium phosphate.

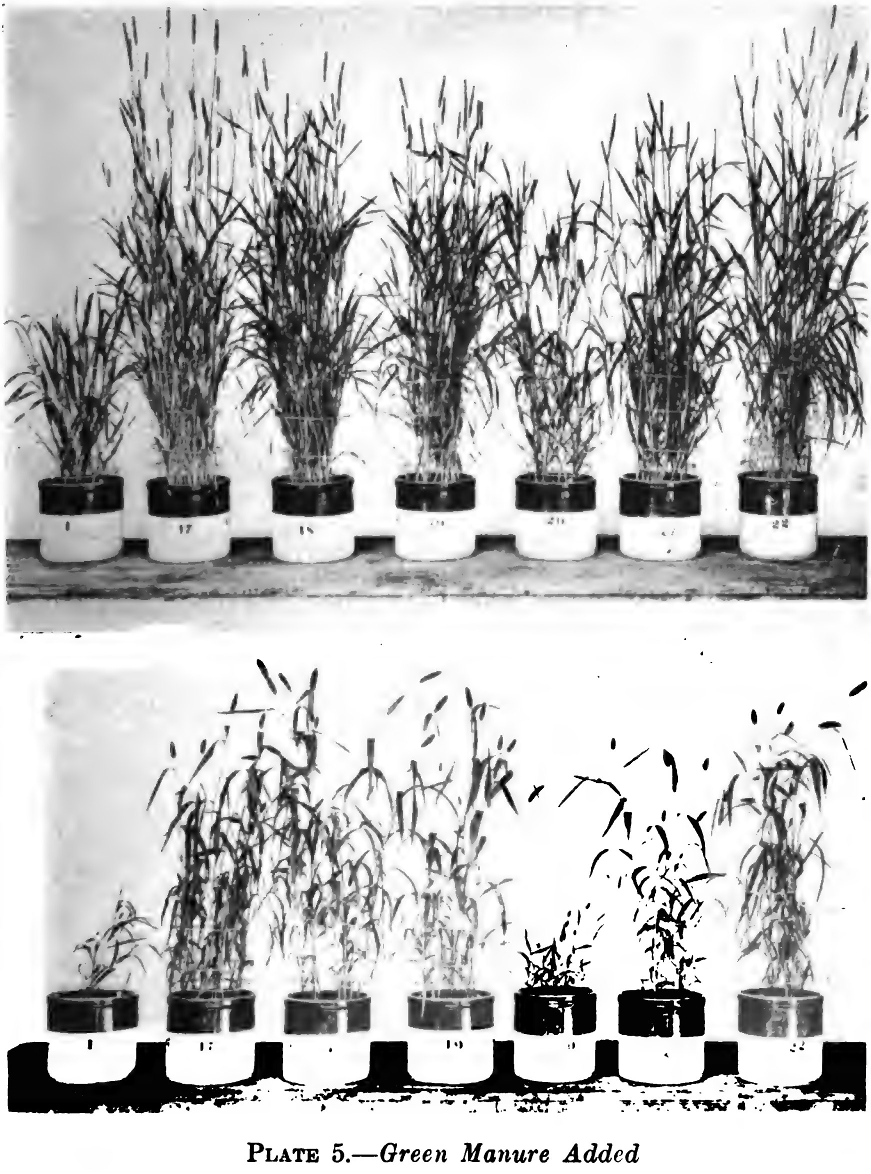


PLATE 5.—*Green Manure Added*

Pot
1—NKL, no phosphorus.
17—NPKLx, phosphoric acid from sodium phosphate.
18—(N1½)PK1½)L, phosphoric acid from sodium phosphate.
19—N(P1½)KL, phosphoric acid from sodium phosphate.
20—N(P2)KL, phosphoric acid from ground (blue) phosphate rock.
21—N(P½)KL, phosphoric acid from double superphosphate.
22—NPKL, phosphoric acid from double superphosphate.

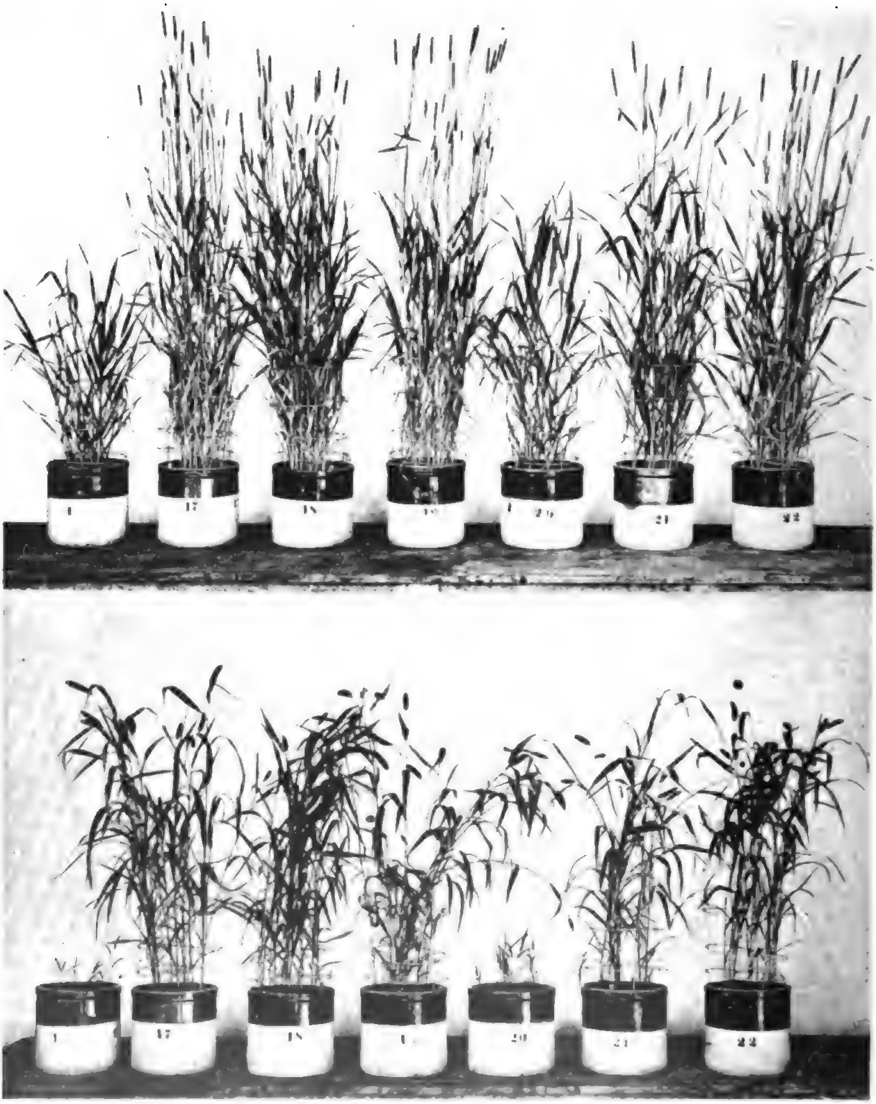


PLATE 6.—*Fallow; no Green Manure Added*

POT
1—NKL, no phosphorus.
17—NPKLx, phosphoric acid from sodium phosphate.
18—(N1½)P(K1½)L, phosphoric acid from sodium phosphate.
19—N(P1½)KL, phosphoric acid from sodium phosphate.
20—N(P2)KL, phosphoric acid from ground (blue) phosphate rock.
21—N(P½)KL, phosphoric acid from double superphosphate.
22—NPKL, phosphoric acid from double superphosphate.

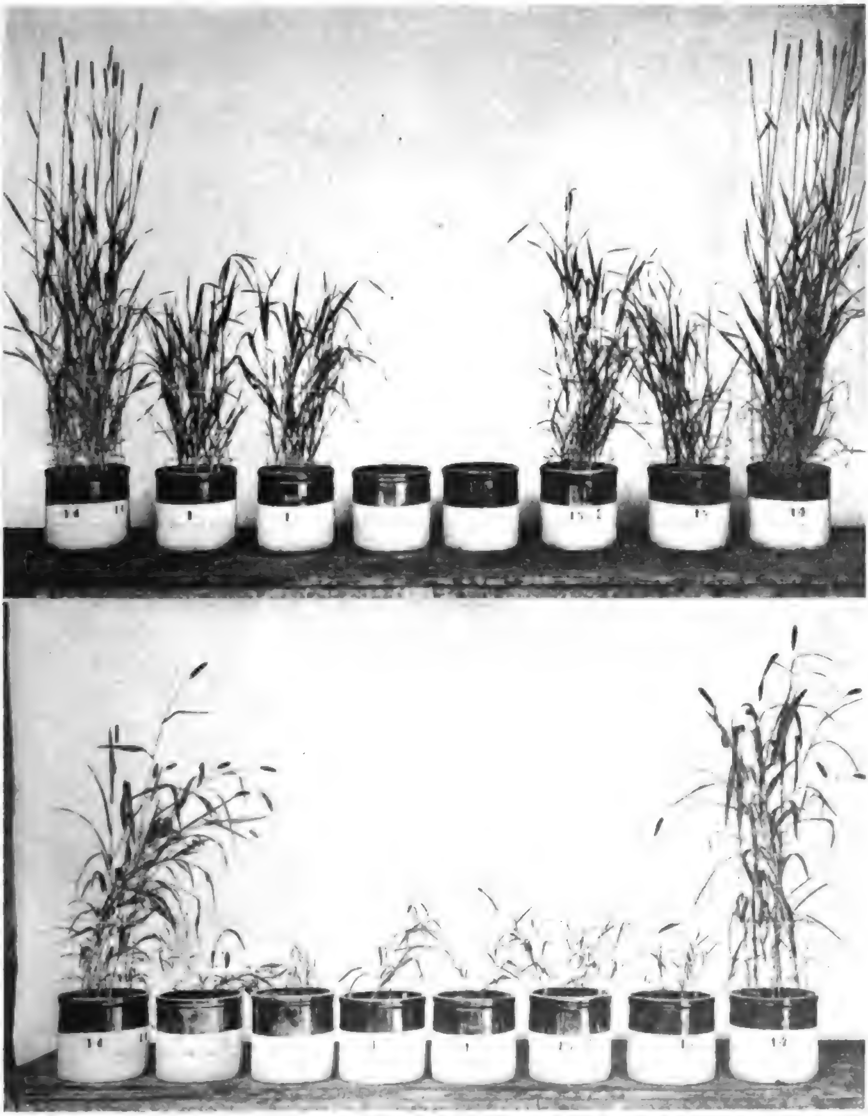


PLATE 7

Pot
1st—NPKL, phosphoric acid from acid phosphate. Green manure added.
2d—NKL, no phosphorus. Green manure.
3d—NKL, no phosphorus. Fallow.
4th—Chec. Green manure.
5th—Check. Fallow.
6th—NPKL, phosphoric acid from ground (blue) phosphate rock. Green manure.
7th—NPKL, phosphoric acid from ground (blue) phosphate rock. Fallow.
8th—NPKL, phosphoric acid from acid phosphate. Fallow.
The pots in the lower photograph, should read 1, 4, 5, 2, 3, 6, 7, 8. Read left to right

PLATE 8

POT
1st—N(P½)KL, phosphoric acid from sodium phosphate. Green manure.
2d—N(P½)KL, phosphoric acid from sodium phosphate. Fallow.
3d—NPKL, phosphoric acid from sodium phosphate. Green manure.
4th—NPKL, phosphoric acid from sodium phosphate. Fallow.
5th—N(P½)KL, phosphoric acid from double superphosphate. Green manure.
6th—N(P½)KL, phosphoric acid from double superphosphate. Fallow.
7th—NPKL, phosphoric acid from double superphosphate. Green manure.
8th—NPKL, phosphoric acid from double superphosphate. Fallow.

PART I—FURTHER OBSERVATIONS ON THE EFFECTS OF PRUNING, ROOT PRUNING, RINGING AND STRIPPING ON THE FORMATION OF FRUIT BUDS ON DWARF APPLE TREES

By A. W. Drinkard, Jr.

In a former paper the writer described a series of pruning experiments on King of Pippins dwarf apple trees, which were begun in the spring of 1913, and gave a record of the effects which the different oper-

Fig. 1—A check tree (IV A b) in full bloom when the trees which were pruned in different ways are not blooming. Photo May 1, 1915.

ations produced on the fruitfulness of the trees in 1914[1]. An outline of the experiments follows but the reader should consult that paper for a

[1]Drinkard, A. W., Jr.—Some effects of pruning, root pruning, ringing and stripping on the formation of fruit buds on dwarf apple trees. Annual Report, Virginia Agricultural Experiment Station, 1913 and 1914, pp. 96-120.

complete discussion of the experiments, for it seems unnecessary to repeat the details of them at this place. Roman numerals indicate series and capital letters indicate plats in this outline.

Outline of Pruning Experiments Carried Out in 1913

I—Pruning at different seasons.
- A. Spring pruning, April 23d, 4 trees.
- B. Summer pruning, June 23d, 4 trees.
- C. Fall pruning, November 21st, 3 trees.

II—Spring pruning on April 23d, accompanied by root pruning.
- A. In spring when sap began to flow, April 23d, 4 trees.
- B. After the foliage was well developed, May 31st, 4 trees.
- C. When fruit buds began to form, June 23d, 4 trees.

III—No spring pruning; root pruning at following dates:
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

IV—Check Series. No pruning of any kind.
- A. Including 4 trees.
- B. Including 4 trees.
- C. Including 4 trees.

V—Spring pruning on April 23d, accompanied by ringing.
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 3 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

VI—No spring pruning; ringing at following dates:
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

VII—Spring pruning on April 23d, accompanied by stripping.
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

VIII—No spring pruning; stripping on the following dates:
- A. When the sap began to flow, April 23d, 4 trees.
- B. When the foliage was well developed, May 31st, 4 trees.
- C. When the fruit buds began to form, June 23d, 4 trees.

The purpose of the present paper is to record the results of these experiments during the years 1915 and 1916. The trees were continued under the sod method of orchard management. There was a good sod of orchard grass, red top, timothy and red clover on the land, and at intervals the grass was cut with a scythe and left on the land as a mulch. The trees received the usual applications of spray materials in the dormant and summer seasons. None of the trees received any pruning whatever with the exception of the cutting of a few shoots which were attacked by fire blight in the summer of 1915, and about the same number of shoots were removed from all trees in the experiments. Therefore, it is not likely that the cutting of blighted shoots interfered with the experimental results.

RECORD OF RESULTS DURING 1915

On May 1st the fruit bud clusters (which have on the average five flowers to the cluster) were counted and these numbers were multiplied by five to determine the number of fruit buds on the trees in the experiments, the results being set forth in table 1.

TABLE I.—*Showing the Number of Fruit Buds on the Trees in the Experiments, May 1, 1915*

	Series	I	II	III	IV	V	VI	VII	VIII
C	l	missing	0	365	1845	50	320	380	1530
	k	180	0	15	3280	530	650	840	880
	j	45	125	0	3685	560	5	1030	730
	i	70	0	0	4490	0	0	1215	2020
B	h	0	0	20	2560	missing	35	0	2900
	g	10	5	10	3660	475	0	425	725
	f	395	0	0	1190	170	0	475	420
	e	45	10	0	2805	0	10	85	455
A	d	1875	5	1990	3515	75	1325	900	225
	c	1345	5	450	2850	1245	2080	1835	600
	b	365	5	10	4590	565	1365	1540	330
	a	1605	25	25	1410	1520	220	1215	280

It may be seen from this table that the check trees of series IV, which were not pruned in any way at the time the experiments were begun, produced far more fruit buds this season than did the trees of the other series which received one form or another of pruning in 1913. This is a reversal of results secured in 1914, and illustrates the tendency of many apple varieties not to produce fruit buds on alternate years, or the biennial habit of bearing.

The year was favorable for the growth of the trees; rainfall was sufficiently frequent and heavy during the growing season to give conditions favorable for vegetation.

FIG. 2—A general view of Series I (left), II, III and IV (right). Note that the blooming on the different series is a reversal of conditions shown in 1914 and 1916. Photo May 1, 1915.

In the latter part of the growing season observations were made on the condition of the foliage on the trees in the different plats. The trees in the three plats of series III had poorer foliage than the check trees; the trees in the plats of all other series had better foliage than the check trees.

Although there was a good crop of bloom on some of the trees this year, yet the bloom form of fire blight killed many blossoms and frost killed part of those that remained, so that very few fruits set on any of the trees. Hence the harvest was very small, but the yields are given by trees in table 2 to make the records complete.

TABLE II.—*Showing the Number of Fruits Harvested from the Trees in the Experiments, September 11, 1915*

C	l	missing	0	0	7	1	6	2	3
	k	0	0	1	11	2	0	2	2
	j	0	0	0	1	5	0	2	1
	i	1	0	0	3	0	0	1	2
B	h	0	0	0	4	missing	0	0	0
	g	0	0	0	6	2	0	1	0
	f	0	0	0	3	2	0	2	4
	e	1	0	0	2	0	0	1	0
A	d	0	0	3	3	0	0	2	2
	c	0	0	0	5	0	2	1	0
	b	1	0	1	3	0	2	1	1
	a	3	0	0	2	0	0	0	1
	Series	I	II	III	IV	V	VI	VII	VIII

In November the season's growth was measured, including the increase in the circumference of the trees, the number of shoots or twigs which grew, and the length of the season's shoot growth. This data is given in table 3. The only trees which actually made less growth than the check trees were those in the plots of series III, which received root pruning without pruning of their tops in 1913.

TABLE III.—*Showing Summary of Growth of Trees in Pruning Experiments During the Season of 1915*

Series, Plat and Number of Trees in Each Plat	Average Circumference Increase During the Year (in inches)	Average Number of Twigs Per Tree	Ann. Twig Growth in Inches	
			Average of the Total Growth	Average of the Mean Growth
I. A. 4 trees	0.4	41	193	4
I. B. 4 trees	0.8	57	325	6
I. C. 3 trees	0.9	60	532	9
II. A. 4 trees	0.2	27	80	3
II. B. 4 trees	0.3	19	55	2
II. C. 4 trees	0.5	18	58	3
III. A. 4 trees	0.2	12	18	1
III. B. 4 trees	0.2	0	2	2
III. C. 4 trees	0.3	26	27	2
IV. A. 4 trees	0.4	41	150	3
IV. B. 4 trees	0.5	21	50	2
IV. C. 4 trees	0.5	34	118	3
V. A. 4 trees	0.3	38	186	4
V. B. 3 trees	0.1	30	67	2
V. C. 4 trees	0.3	41	143	3
VI. A. 4 trees	0.1	17	33	2
VI. B. 4 trees	0.4	27	59	2
VI. C. 4 trees	0.5	29	75	2
VII. A. 4 trees	0.4	43	238	5
VII. B. 4 trees	0.1	41	148	3
VII. C. 4 trees	0.4	36	108	3
VIII. A. 4 trees	1.0	45	179	3
VIII. B. 4 trees	0.6	29	60	2
VIII. C. 4 trees	0.4	29	66	2

RECORD OF RESULTS DURING 1916

The trees received the dormant spray of winter-strength lime-sulphur solution before the buds opened, and also the usual summer sprays at the proper time. The trees were not pruned in any way this season

There was a heavy sod on the land and the grass was cut several times during the season and left on the ground as a mulch.

FIG. 3—A general view of Series I (left), II, III and IV (right). The trees in Series I, which were winter pruned in 1913 have scarcely any bloom. The trees in Series II and III, which were root-pruned in 1913 have heavy crop of bloom. The check trees of Series IV show very little bloom. Photo May 4, 1916.

On May 4th the number of fruit buds on each tree was determined in the manner previously described, and this data is presented in table 4.

TABLE IV.—*Showing the Number of Fruit Buds on the Trees in the Experiments, May 4, 1916*

C	l	missing	1145	3540	2535	1705	2430	1385	1215
	k	2220	450	1600	140	160	185	210	925
	j	1365	3285	3800	155	195	3150	90	2290
	i	1570	805	145	15	1930	1270	30	90
B	h	1145	505	1810	15	missing	1005	190	40
	g	2865	2255	2855	5	355	935	240	1375
	f	440	1735	1840	560	285	1615	255	2180
	e	1355	125	570	0	1200	875	1670	2345
A	d	0	585	205	0	955	25	155	2075
	c	10	1760	0	20	375	20	70	2800
	b	860	1610	2325	70	1030	115	110	3340
	a	160	2140	1990	245	180	2205	360	2280
	Series	I	II	III	IV	V	VI	VII	VIII

The season was favorable for fruit production and many trees in the experiments fruited well. Table 5 shows the yield of fruit from every tree by weight and table 6 shows the number of fruits borne by every tree in the experiments. While the yield is somewhat irregular as regards individual trees, yet it may be seen that there is a clear difference

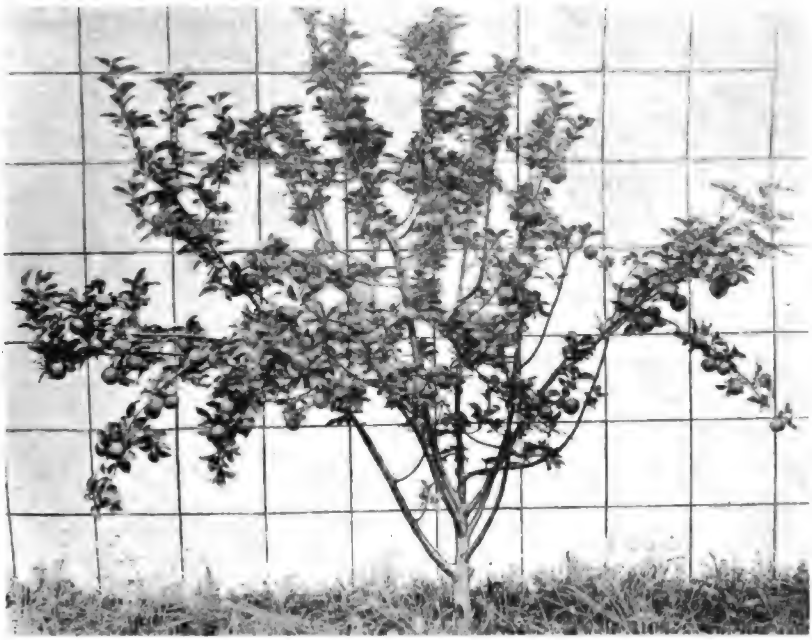


Fig. 4—This tree (II A a) was pruned and root-pruned in 1913. It now carries heavy crop of fruit. The background is ruled in square feet. Photo July 20, 1916.

running through the plats due to the pruning treatments which the trees received in 1913.

Table V.—*Showing Harvest Records Expressed in Pounds for the Trees in the Experiments, September 14, 1916*

C	l	missing	30	5	97	21	31	25	23
	k	40	7	19	5	5	7	7	22
	j	44	17	21	5	4	20	3	30
	i	36	21	4	⅛	14	13	1½	1½
B	h	29	18	6	1	missing	17	3	1
	g	58	34	1	0	7	15	5	23
	f	27	21	19	13	9	12	8	21
	e	30	2	4	0	12	4	11	3
A	d	0	17	7	0	12	½	4	9
	c	¼	14	⅛	1	12	1	3	6
	b	7	15	10	5	6	4	6	9
	a	10	30	16	10	9	17	12	34
	Series	I	II	III	IV	V	VI	VII	VIII

TABLE VI.—*Showing Harvest Records Expressed in Number of Fruits for the Trees in the Experiments, September 14, 1916*

C	l	missing	110	31	440	105	161	135	131
	k	141	41	87	26	29	39	44	176
	j	180	77	83	39	22	111	18	202
	i	146	93	23	1	93	72	5	11
B	h	133	87	31	8	missing	89	24	8
	g	237	144	10	0	35	113	39	137
	f	115	93	104	83	62	62	53	101
	e	137	11	36	0	74	24	63	17
A	d	0	102	51	0	52	3	19	51
	c	2	69	1	5	39	12	17	36
	b	47	68	52	29	32	22	32	48
	a	58	141	71	52	48	97	48	143
	Series	I	II	III	IV	V	VI	VII	VIII

In November growth measurements were again taken, and these show that circumference increase during this year and shoot or twig growth was better on trees in the plats which received only top pruning and

FIG. 5—King of Pippins fruiting in the pruning experiments. Photo Sept. 14, 1916.

better on the trees in the check plats than on the trees which were root pruned, ringed or stripped. No doubt the crop of fruit for the current season influenced the amount of vegetative growth. Table 7 shows a summary of growth of trees on all the plats.

TABLE VII.—*Showing Summary of Growth of Trees in the Experiments during the Season of 1916*

Series, Plat and Number of Trees in Each Plat	Average Circumference Increase During the Year (in inches)	Average Number of Twigs Per Tree	Ann. Twig Growth in Inches: Average of the Total Growth	Ann. Twig Growth in Inches: Average of the Mean Growth
I. A. 4 trees	0.6	106	702	6
I. B. 4 trees	0.6	111	525	5
I. C. 3 trees	0.8	117	645	6
II. A. 4 trees	0.2	126	357	3
II. B. 4 trees	0.2	96	395	4
II. C. 4 trees	0.4	83	423	5
III. A. 4 trees	0.3	73	197	3
III. B. 4 trees	0.2	89	268	3
III. C. 4 trees	0.4	115	247	2
IV. A. 4 trees	0.7	120	362	3
IV. B. 4 trees	0.5	121	293	2
IV. C. 4 trees	0.5	153	430	3
V. A. 4 trees	0.5	97	250	3
V. B. 3 trees	0.3	109	163	1
V. C. 4 trees	0.6	87	283	3
VI. A. 4 trees	0.4	121	257	2
VI. B. 4 trees	0.2	71	139	2
VI. C. 4 trees	0.4	90	254	3
VII. A. 4 trees	0.9	75	305	4
VII. B. 4 trees	0.7	63	192	3
VII. C. 4 trees	0.6	70	244	3
VIII. A. 4 trees	0.2	74	250	3
VIII. B. 4 trees	0.3	63	144	2
VIII. C. 4 trees	0.4	72	210	3

SUMMARY

Observation during two subsequent years confirm the conclusions drawn in the previous report on this experiment. (Note citation at beginning of this paper). Although they have received no form of pruning since 1913, the trees in the experimental plats continued to show marked effects in fruit bud formation due to the original treatments. The recurring effects of these treatments are noteworthy and have great significance in experimental work with fruit trees, for they indicate that the influence of a particular treatment or operation may extend over a long period of time, and this factor should be reckoned with in handling fruit trees for experimental purposes.

The habit of some varieties of apples to fruit on alternate years should be borne in mind in interpreting these results. It is a well known fact that many varieties fail to produce fruit buds on any extensive scale in a year following one of heavy fruiting, but the physiological reason for this has not been clearly explained. It may be seen from table 1 that the trees which fruited heavily in 1914, produced relatively few fruit buds in 1915, and those which fruited lightly in 1914 produced many fruit buds in 1915. Table 4 which gives results for 1916, shows almost a repetition of the results of 1914 with possibly an accentuation of the effects resulting from the different treatments.

The treatments given these trees apparently shifted the fruiting year, since the check trees bloom on the alternate year as compared with the treated trees. Moreover, the check trees have not produced during the period of the experiments as many fruit buds as the treated trees.

PART II—STUDIES ON METHODS OF PROTECTING RINGING WOUNDS ON APPLE TREES TO PROMOTE THEIR HEALING

By A. W. Drinkard, Jr., and A. A. Ingham

One practical objection to the ringing of fruit trees for the purpose of inducing fruitfulness is the uncertainty of the healing of the wound and the liability of serious if not fatal injury to the trees in those cases where proper healing does not follow the operation. Sometimes such wounds heal well and sometimes they do not. Since ringing is usually done at a time when growth processes are going on rapidly, it would seem that the factor of moisture supply is of prime importance. The presence of sap in abundance in the tissues of the tree, which in turn is dependent upon the presence of sufficient moisture in the soil surround-

Fig. 6—An apple tree about twelve years old, variety unknown. Note that the tree has a double trunk. The trunk on the right side was ringed in the early part of the summer of 1914. The ringing wound may be discerned just above the lower branch on the right trunk. The photograph was taken April 30, 1915. The part of the tree which was ringed carries a heavy crop of bloom; the part not ringed does not carry any bloom.

ing the root system of the tree, and the presence of moisture on the wound area, seem to determine proper healing, granting that temperature and other environmental factors are favorable for growth. If the wound area is exposed to direct sunlight or to drying winds, the tender tissues

FIG. 7—View of a ringing wound three months after the operation. The tree was twelve years old when the ringing was done on May 22, 1914, and the following three seasons showed no marked stimulation of fruit-bud development. The variety is Arkansas apple and the trunk of the tree was twenty-four inches in circumference when ringed.

exposed in the wound area soon become dead by desiccation and then healing or regeneration of new tissue is impossible, and the only way the wound can be repaired is by roll-healing, where rolls of tissue advance from the borders of the wound and by their meeting and union cover the wound area thereby repairing the injury.

In August, 1915, the senior author performed a series of experiments to determine a method of protecting ringing wounds with the view of finding means of avoiding the liability of permanent injury where ringing is used as a means of inducing fruitfulness in trees. Full dwarf apple trees of the variety Querrenden were used for the experiments and 48 trees were included in the tests. This block of trees was divided into 12 plats of 4 trees each.

Plat 1.—An annular cortical section was removed from the trunk of each tree, about 12 inches above the ground, the width of the sections being ½ inch for the first tree, ¾ for the second, 1 for the third and 1½ inch for the fourth tree. Each wound was sealed immediately with a strip of zinc oxide adhesive plaster. After two weeks the protectors were temporarily removed for an examination of the wound and it was found that healing was proceeding favorably. After six weeks it was found that healing was almost complete. On November 5th the adhesive plaster protectors were finally removed and the healing was found to be such that no permanent injury to the trees is likely to result from the operation.

Plat 2.—The trees were ringed as previously noted, but the wounds received no protection, so that this plat might serve as a check in testing the efficiency of the various protectors used in the experiments. Two weeks later the tissue in the wound areas had dried and there was no healing. After four weeks there was a slight downward growth from the bark cambium of the upper border of the wound. On November 5th the wound area was dry and there was no healing within the wound area proper. The trees in this plat were permanently injured by ringing.

Plat 3.—The trees were ringed as previously noted, and the wounds were protected by strips of mechanic's friction tape. Healing was visibly progressing in two weeks and proceeded favorably through the remainder of the growing season and on November 5th, at which time the protectors were removed, healing was practically complete and no permanent injury to the trees will result from the operation.

Plat 4.—The trees were ringed as previously noted, and the wounds were protected by tying over them paper which previously had been dipped in hot paraffin. After four weeks, healing was proceeding satisfactorily in the wounds of all trees, and at the end of the growing season the repair was such as to insure that no permanent injury would result from the operation. The width of the ringing wound was not a material factor in the healing process. The paraffin paper protector very effectively prevented loss of moisture from the wound area and also retained around the wound an atmosphere practically saturated with mois-

ture, which was shown by the accumulation of drops of water on the inside of the paraffin paper protector.

Plat 5.—Not ringed at all. Used as check.

Plat 6.—The trees were ringed as previously noted. Candle wicking was rolled together and wrapped around the wound area so as to cover all the wound, and the loose ends were inserted in a bottle of distilled water. It was thought that by capillary action the candle wicking would bring up water in sufficient amount to keep the wound moist, but owing to the compactness of the material used the water was not supplied properly and poor healing resulted, because large areas in the wounds became dry.

Plat 7.—The trees were all ringed in the same way by removing an annular cortical section, ¾ inch wide from the trunk. The candle wick apparatus was again used, but bichloride of mercury was used in the distilled water at the rate of 1 gram to 1,000 cubic centimeters, thinking that the bichloride of mercury would serve as a disinfectant to prevent the growth of bacteria and fungi on the wound area. The bichloride of mercury proved to be very injurious to the tender tissues and therefore no healing took place.

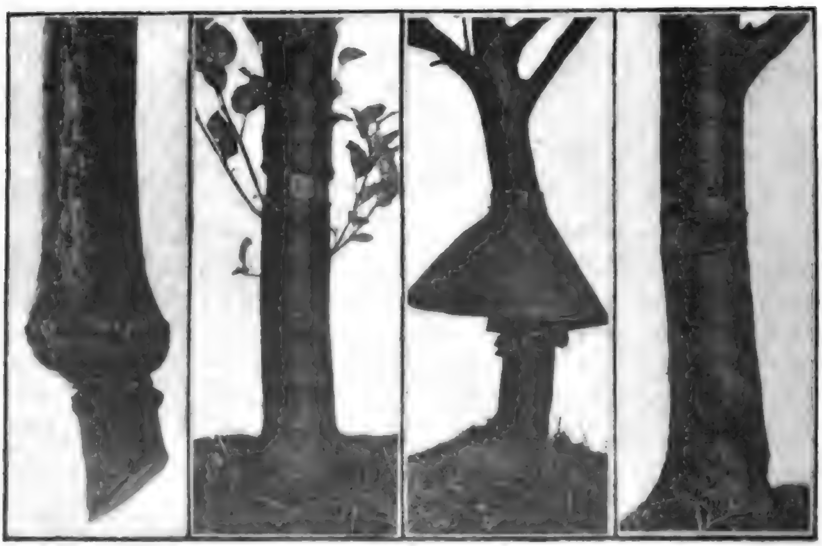


FIG. 8—Read from left to right. The first view shows part of a small branch of a Gano apple tree on which the ringing wound did not heal; note enlargement above the wound. The second view illustrates the tendency of trees to throw out shoots below ringing wounds which fail to heal. The third view shows Scott's tree protector adjusted to shade a ringing wound. The fourth view shows complete healing of a ringing wound on a full dwarf Querrenden apple tree.

Plat 8.—The trees were ringed as noted in the case of plat 1. A loose roll of cheese cloth was wrapped around the wound area, covering all parts of the wound, and the loose ends of the roll were inserted in a bottle of distilled water. This arrangement supplied water nicely and kept the wound area moist and healing proceeded in a satisfactory manner. This apparatus is efficient, but it is too cumbersome for practical use.

Plat 9.—A ¾ inch ringing wound was made on all trees in this plat and the wounds were protected with strips of adhesive plaster. The results were the same as noted in plat 1.

Plat 10.—A ¾ inch ringing wound was made on all trees, and the wound was protected by sealing with mechanic's friction tape. The results were the same as those noted in plat 3.

Plat 11.—A ¾ inch ringing wound was made on all trees in the plat and protection was given by tacking Scott's tree protectors above the wound area, which shaded the wounds perfectly and also furnished protection against direct air currents. At the end of the season, there were some spots which had not healed, but regeneration had gone on sufficiently to insure that no permanent injury would result from the operation.

Plat 12.—A ¾ inch ringing wound was made on the trunks of all the trees. The wounds were protected by tying paraffin paper over the wounds. The results were the same as those noted in plat 4.

The experiments this season were performed too late to produce any material increase in the formation of fruit buds on the treated trees, but they showed clearly the possibility of protecting wounds so that healing might proceed properly. The adhesive plaster, friction tape, paraffin paper, cheese cloth inserted in water, and Scott's tree protectors were all satisfactory. The paraffin paper protector is the simplest and cheapest means of accomplishing the desired end.

The growth of bacteria and fungi on the tissue of the wound area was a source of some trouble, for these parasites often kill the tender tissue which develops in the wound area. The prevention of such infection is an important factor in this work.

Owing to the fact that the ringing operations were made late in the season (August 5, 1915), there was no noticeable stimulation of fruit bud formation, and in the spring of 1916, the trees in both treated and check plats bloomed very sparingly. However, the influence of these operations was evidenced by a strong stimulation of fruit-bud development on the treated trees as compared with the check trees in the spring of 1917.

During the season of 1916 the junior author performed a series of experiments to determine (1) the conditions which favor proper healing of ringing wounds without interfering with the object sought through

ringing and (2), the practicability of controlling the factors which influence the proper healing of such wounds.*

Experience of last year's work suggested the following problems relative to the healing of ringing wounds:

I—Influence of the time the wound is made.
II—Influence of the width of the wound, with respect to the circumference of the tree.
III—Vigor and health of the tree.
IV—Effect of available water in the soil.
V—Prevention of loss of water from the wounds.
VI—Effects of paints and other similar preparations.
VII—Effects of disinfectants, with and without paraffin paper protectors.
VIII—Effects of moisture, artificially supplied to the wounds.

To answer these questions, full dwarf apple trees, planted in 1906, were selected and the ringing was done during the spring and summer of 1916. The number of trees selected for experiment on each of the above problems, and the details of procedure will be given in connection with the presentation of the results and discussions which follow.

I. Influence of the Time the Wound Is Made on the Process of Healing.—Knowing that the differentiation of fruit buds on apple trees begins the latter part of June†, the dates on which the ringing was to be performed were selected so that two would fall before, one approximately near, and two after this date. With this idea in view, the following dates were decided upon: May 24th, at which time the first leaves were mature; June 7th, June 28th, or the time of fruit bud differentiation; July 12th and July 26th. On each of these dates four trees were ringed with a ¾ inch ring, and the wounds in each case were covered with protectors of paraffin paper, tied above and below with raffia. The ringing was done at a height varying between 8 and 12 inches, and high enough in nearly every instance to prevent possible shading by grass. It might be well to state at this point that three types of healing were noticed. First, the development of a smooth film of new tissue over the entire wound area. Secondly, the meeting and union of tissue protruding over the wound area from the upper and lower margins of the wound. And, thirdly, a combination of the above two types. The first occurred uniformly where the ringed area was not disturbed, either mechanically or by treatment with paints or disinfectants, after the removal of the bark and subse-

*Ingham, A. A.—A study of the Healing of Wounds made by the Operation of Ringing Apple Trees. Unpublished Thesis, V. P. I. Library.

†Drinkard, A. W., Jr.—Fruit Bud Formation and Development. Ann. Rep. Va. Agr. Exp. Station for 1909 and 1910, pp. 159-205.

quent protection of the wound with paraffin paper to prevent evaporation. The last two types were common on wounds left unprotected, or in cases where the cambium cells were injured by paints or disinfectants. The final examination of the wounds was made January 2, 1917, and it was seen that the time of making the wounds, within the limits selected, had little effect upon the healing. In every case the paraffin paper protector prevented evaporation from the wounds, and the healing was perfect. In several instances, fungous infections caused a great amount of

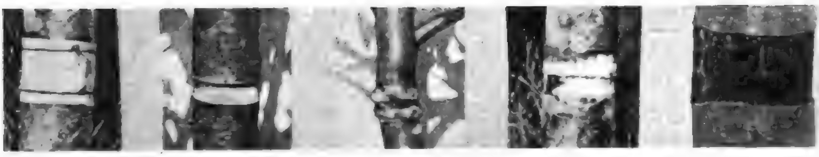


FIG. 9—Read from left to right. The first view shows paraffin paper protector tied in place; the second shows healing of a ringing wound by the development of new tissue over the entire wound area; the third shows incomplete healing by protruding tissue from upper and lower margins of the wound; the fourth shows healing after the paper protector was removed and the dark spot shows fungous growth on the new tissue; the fifth shows complete healing of a 3-inch ringing wound (about 1/6 natural size).

damage subsequent to complete healing, which infections must have been made at the time of ringing, as shown by their presence soon after the wounds were made.

II. Width of the Ringing Wound.—This experiment was outlined to determine whether or not the width of the wound should be proportiona to the size (circumference) of the tree. To answer this question three classes of trees, as regards circumference, were selected. First, branches of full dwarf trees, varying in circumference from 3 to 5 inches, secondly, full dwarf trees varying from 7.5 to 11 inches, and, thirdly, half dwarf trees with circumferences from 11 to 15 inches. The maximum width of ringing wound used on the smaller trees was 1½ inch; and on the larger trees 3 inches. All wounds were covered with paraffin paper protectors

The wounds were examined January 2, 1917, and the observations showed that for each given range of circumference, the extreme width selected was well within the bounds of safety, and that there was no perceptible difference in healing between the narrow and wide rings. It is doubtful whether a tree would ever be ringed after the circumference of the trunk exceeded 15 inches, and should it be ringed at all, a ¾ to 1-inch ring would likely produce the desired results, disregarding entirely the factor of circumference. However, should the ring be made wider, the healing would no doubt still be complete, provided the width was not too great. What the limits of width are cannot be foretold from the

data secured, but it was plainly seen that it was in excess of the greatest width employed, namely, 3 inches.

III. Vigor and Health of Trees.—In this division, conclusions were to be drawn from observations made of the healing of wounds on vigorous trees and on weak trees, which had received the same treatment. These observations were made on the trees contained in Division I. While the trees varied somewhat in vigor, this variation was not sufficient to produce any perceptible difference in the healing of the wounds. Weak trees have a tendency to fruit too freely, and the ringing operation would not be used on such trees.

IV. Effect of Available Water for the Tree Roots on Healing of the Wounds.—For this study, four trees were ringed with a ¾-inch ring on June 29th, and the wounds were protected with paraffin paper protectors. These four trees were to receive irrigation, as needed, to supply abundant moisture for the roots. Up to the date of ringing, the seasonal rainfall had been ample. On the same date, four other trees were ringed and protected in a similar manner, and left as checks on the four trees mentioned above. From the meteorological records herewith given, it will be seen that no irrigation was necessary. Therefore, no comparison between the two groups was made, and no conclusions can be drawn at this time.

Rainfall During the Period of This Experiment

1916	Total Rainfall (inches)	Average Daily Rainfall (inches)	Number of Days on Which 0.1-Inch or More Rain Fell
May 22–31	3.80	0.38	4
June	8.07	0.26	11
July	7.79	0.25	10

V. Prevention of Loss of Water From the Ringing Wounds.—Four trees were ringed on June 28 with ¾ inch rings for use with each type of protector. The protectors used were the following:

1. Paraffin paper.
2. Zinc oxide adhesive plaster.
3. Four check trees, ringed but not protected.
4. Shading by Scott's tree protector.
5. Ordinary grafting wax.

The paraffin paper protectors consisted of strips of good, well sized, letter paper, dipped in melted paraffin. The strips were wrapped around the trees, being wide enough to give ample room above and below the

wound to permit tying with raffia. The zinc oxide adhesive plaster was two inches wide, which gave sufficient width to insure a good attachment. The plaster was wrapped once around the tree, with a slight lap. Scott's tree protectors were tacked tightly above the wounds, the actual distance being about one inch. This gave a good shade, and in that way reduced the loss of moisture from the wounds. The last protector used was ordinary grafting wax. This was worked with the hands until soft, and then applied to the wounds as a ribbon.

FIG. 10—Read from left to right. The first view shows paraffin paper protector in place; the second adhesive plaster in place; the third shows healing after the adhesive plaster is removed; the fourth shows grafting wax partly removed; the fifth view shows Scott's tree protector partly removed (about 1/6 natural size).

From the final examination it was seen that all the protectors permitted complete healing. Consequently, to determine their relative value, the cost of application and the prevention of fungous attacks must be considered. On this basis, the paraffin paper protectors stand foremost, with adhesive plaster, Scott's tree protector, checks, and grafting wax ranking in the order named.

VI. Effects of Paints and Similar Preparations.—In this division the trees were ringed on June 29th, and four trees were used for each of the following treatments:

1. White lead and linseed oil paint.
2. Nu-Tree.
3. North Carolina pine tar.
4. Soft grafting wax.
5. Checks, ringed, not protected in any way.
6. Checks, not ringed.

The white lead paint was made of pure white lead and linseed oil, fairly thick. The paint was applied with a brush, about ten minutes after the ringing wounds were made. Nu-Tree is a patent preparation, a can of which was on hand when the experiment was planned. No directions for its use were available, but assuming that it was a dressing for tree wounds, it was applied to them for that purpose. The North Carolina pine tar was very thin, and it spread considerably after being applied with the brush. This material is of vegetable origin, and other tars, of

different chemical composition should have been added to the list of treatments. However, Nu-Tree appeared to resemble such, and possibly gave an indication of their value.

The soft grafting wax consisted of ordinary grafting wax to which linseed oil had been added. It required very little heat to cause it to melt, as the day of application was a warm one. The melted wax was then applied with a brush.

FIG. 11—Read from left to right. The first view shows lack of healing where white lead paint was used; the second shows injurious effects on Nu-Tree paint (the white spots were made by cutting away the bark with a knife to expose the cambium, above and below the original wound, killed by the penetration of this paint); the third shows that North Carolina pine tar prevented healing; the fourth shows bad effects from painting with soft grafting wax; the fifth snows irregular healing on an unpainted check tree (about 1/6 natural size).

The four check trees that were ringed and left unpainted were for comparison with the painted trees in this division.

The results of these treatments showed that the paints and similar materials used not only failed to promote healing, but actually retarded or entirely prevented it. In this respect, Nu-Tree was the worst of the materials used; white lead linseed oil paint and North Carolina pine tar were similar in their effects, and soft grafting wax was the best, but this "best" was so far below the results obtained with the unpainted, ringed checks. that the use of such treatments would be only inviting disaster. This conclusion might be considered an extension of those of Howe* to a different type of wound from those with which he worked. Nu-Tree not only prevented film healing, but killed back the cambium of the wound edges to such an extent, that when slight rolls of new tissue began to protrude over the wound the distance between them was not that of the original ring. but rather that distance increased two or three fold. White lead linseed oil paint and North Carolina pine tar acted in a similar manner, but not quite to such a damaging extent as Nu-Tree. The soft wax treatment prevented film healing and probably checked roll healing, but there was no killing back of the cambium at the wound edges. The untreated, ringed checks showed medium to good healing, but the successful healing of these

*Howe, G. H.—Effects of Various Dressings on Pruning Wounds of Fruits Trees. N. Y. Agr. Exp. Sta., Bul. No. 396. 1915.

wounds was due to shading, as shown by the fact that the best healing was on the northeast side of the wound, and the abundant rainfall during the time of healing was conducive to proper healing of the checks. But even under the most adverse climatic conditions, it is doubtful whether the healing of untreated wounds of this type could ever be as poor as that shown by the treated trees in this division.

VII. Effects of Disinfectants, With and Without Paraffin Paper Protectors.—Four trees were ringed and treated with their respective disinfectants on July 1st, ¾-inch rings being made. After disinfecting, paraffin paper protectors were applied to three of the ringed trees, while the fourth, in the case of each disinfectant, was left unprotected. The disinfectants used are listed below.

1. Copper sulphate, 1 percent.
2. Formaldehyde, 10 percent.
3. Bichloride of mercury, 1/10 of 1 percent.
4. Carbolic acid, 2½ percent.
5. Salicylic acid, saturated solution.
6. Creolin, 10 percent.

The copper sulphate disinfectant was made up so as to have a 1 percent solution. The wounds were well washed with this material, and then, with the exception of one tree, paraffin paper protectors were applied. All the other materials were made up according to the percents named, and the same plan of procedure followed as with those treated with copper sulphate.

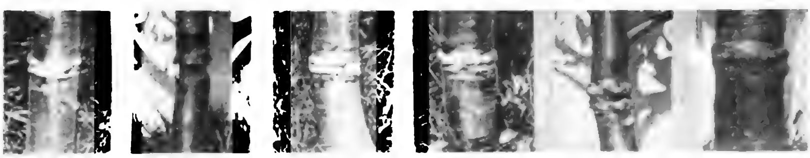


FIG. 12—Read from left to right. These wounds were disinfected and protected with paraffin paper, and the photographs were made after the protectors were removed. The first view shows good healing with copper sulphate solution as a disinfectant; the second shows injury and absence of healing where formaldehyde was used; the third shows healing where bichloride of mercury was used; the fourth shows healing where carbolic acid was used; the fifth shows imperfect healing where salicylic acid was used; the sixth view shows healing where creolin was used (about 1/6 natural size).

The results indicate that the use of disinfectants in conjunction with paraffin paper protectors is the best method to promote healing. The protector alone, in Division I, gave perfect healing but no insurance against fungous attacks. In this division, the disinfectant alone, in every case, was either a complete failure, or very close thereto. But when both were

used together, the results show that with certain disinfectants complete healing and freedom from fungi are to be expected. The best disinfectants for this work were salicylic acid and creolin. Carbolic acid and copper sulphate tied for second place, while bichloride of mercury and formaldehyde followed in the order named, the latter two being unfit for this purpose. Different strengths of these solutions might produce results varying from the above, but from the standpoint of fungous control along with healing, the given order of superiority is probably correct. All the treatments prevented fungous attacks, but with two disinfectants, killing of the cambium occurred. This action was seen to be very bad with formaldehyde, and less so in the case of bichloride of mercury. The killing in the last case, however, was more or less superficial, the injury not extending entirely through the bark to the wood, and consequently the formation of rolls of tissue at the margins of the wound was not greatly hindered. Again the predominance of healing by protruding rolls is very striking, but this is a direct result of the application of disinfectants on the cambium cells of the freshly exposed wood.

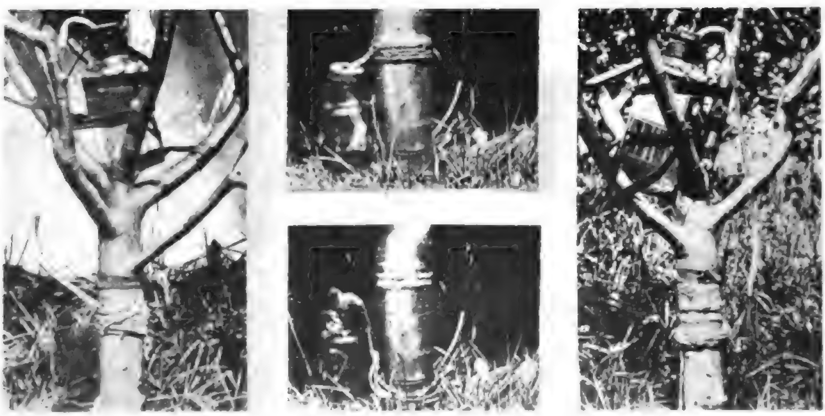


FIG. 13—Showing methods of supplying moisture to ringing wounds by siphon and capillary actions: also healing resulting from the two methods (size reduced).

VIII. Effects of Moisture, Artificially Supplied to the Ringing Wounds. —The trees in this division were ringed with ¾-inch rings on June 30th. In order to keep the wounds moist, two types of reservoirs for furnishing water were used. First, one located at the base of the tree, from which cotton wicking, similar to that usd in a miner's lamp, carried the water to the wound. In the latter type, the reservoir was placed in the tree, and the water carried therefrom by siphon action to a band of wicking, placed around the wound. This last type may appear to be quite a useless

novelty, but at the time the experiment was started, there was considerable doubt as to the water carrying efficiency of the wicking alone, and therefore the siphon action was employed to furnish the necessary moisture. Four trees were used for each type.

Moisture is unquestionably the most important factor in the healing of wounds, and this may be supplied by preventing its evaporation or escape, or by artificial application, as was done in this division. The difference between the results obtained by the two types of reservoirs was in favor of the reservoir situated below the wound, but this difference was only slight. However, as both of these types are expensive to begin with, and require considerable attention, the use of paraffin protectors to prevent evaporation is preferred. On comparing these results with those on the ringed checks in division V, the good healing secured in the latter cases would seem to make it inadvisable to use any means at all to supply moisture. But this excellent healing on unprotected, ringed trees was no doubt due to the unusually heavy precipitation during the past spring and summer, with the consequent humidity of the air and dampness of the soil. To these factors might be added the effect of shading by the closely planted dwarf trees. Under ordinary conditions, the value of moisture supply, or conservation, would be more striking than in the results secured during this season.

SUMMARY

The object of this study was to secure data on the healing of wounds made by the operation of ringing. The work was done during the years 1915 and 1916, and the following conclusions seem justified.

Although this operation is a drastic one, still complete healing may be expected when the work is properly done, and the wounds protected. The time to do the ringing in this locality may vary between May 24th and July 26th, or possibly between even wider limits, depending upon seasonal conditions, and the period of fruit bud differentiation should be the controlling factor in selecting the date on which to do this work.

The width of the ring need not be varied to accommodate increased or decreased circumferences, within certain limits, as complete healing was secured with all widths and circumferences used in this experiment.

Equally good healing was secured on fairly vigorous trees as on trees appearing very vigorous. However, it is doubtful whether weak trees would show as good results, but as weak trees are inclined to be overproductive, rather than unproductive, the advisability of ringing such trees would be questionable from the start.

Moisture is essential for the proper healing of ringing wounds, and this may be supplied artificially, or conserved by preventing evaporation. The latter method is probably the better, and paraffin paper protectors have proved to be the most efficient means to accomplish this end.

Paints and similar preparations are unfit as aids to the healing of ringing wounds. In no case did any of the materials that were used promote or permit healing, and thereby proved themselves worse than no treatment at all.

The use of disinfectants was a failure when applied alone, but when used in conjunction with paraffin paper protectors, perfect healing and protection against fungi and bacteria were secured with certain ones. Salicylic acid and creolin gave the best results. Copper sulphate was also good.

Finally, when the wounds are properly made, as regards time and width, on apple trees, and then disinfected, and protected with paraffin paper, complete healing may be expected. The practical value of this operation is yet to be determined, but should anyone desire to ring apple trees, he may do so without great danger of injury to them, provided the proper precautions are used.

THE EFFECT OF HYBRIDIZATION ON MATURITY AND YIELD IN CORN

By T. B. Hutcheson and T. K. Wolfe

Many of the corn hybridization experiments heretofore reported have had to do with the effect of hybridization on yield and vigor of the plants, principally in the F_1 generation. The investigations so far conducted show that the effect of hybridization diminishes after the first generation until finally the effect is negligible. A few investigations have shown that frequently hybridization produces an effect in the current year as well as in the F_1 generation, and frequently this effect is to increase the yield. On account of the increased vigor often found in hybrid corn, the plants are apparently enabled to withstand drought better. If hybrid corn is found to be of earlier maturity than the parents, it will be of advantage in many sections; especially is this true in sections where growing seasons are short.

Review of Literature

This experiment was begun primarily for the purpose of studying the effect of hybridization on maturity. Below is reviewed some of the literature pertaining to the inheritance of earliness and lateness in plants.

Love[19] studied, by biometrical methods, the relation of seed ear characters to earliness of corn. In conclusion this writer says: "Smaller ears do not give earlier corn and as the corn becomes earlier the ears do not necessarily decrease in size, provided one does not unconsciously select small ears for seed." From the observations of the writers and others[27] it seems that early maturing varieties of corn produce smaller yields than late maturing varieties. However, it seems by proper selection within a variety, the grower can increase earliness without decreasing the yielding capacity. From the results of our experiment, increased earliness, due to hybridization, has not lowered the yield; there seems to be a tendency to the reverse. However, there is not a sufficient number of crosses to draw a conclusion in regard to this point.

Hayes and East[15] report as follows, in regard to maturity of some F_1 generation corn hybrids: "While no exact figures can be given, it is believed that the hybrid matures earlier than the average date of maturity of the parents. The reason for this is that increased vigor, due to crossing, is often shown by rate of growth as well as by actual size attained."

At the Wisconsin station[21] an F_1 hybrid between Wisconsin No. 8 and Toole's North Star matured in 126 days. The previous year, Wisconsin No. 8 matured in 120 days and North Star in 133 days.

Keeble and Pellew[18] found on crossing two varieties of peas which differed markedly in time of flowering, that the F_1 generation plants were intermediate in time of flowering. Their results indicate that lateness and earliness are connected with certain vegetative characters. It seems probable, at least in this experiment with peas, that lateness is dominant to earliness and the apparent intermediacy is due to the connection of these characters with certain other characters.

Mendel[6] states, concerning the inheritance of time of flowering in peas, as follows: "As regards the flowering time of the hybrids, the experiments are not yet concluded. It can, however, already be stated that the time stands almost exactly between those of the seed and pollen parents xxxxx."

Belling[2] found on crossing the Florida velvet bean with the Lyon bean, that the F_1 generation hybrids were later in flowering than either parent. In later generations there was segregation in regard to earliness and lateness. In the report of 1913 the writer mentioned five races which had segregated and shown different dates of flowering. He says: "I regard the isolation of these five races constant to different degrees of earliness as a proof of the segregation of genetic factors affecting earliness and lateness in the microspores and megaspores of the F_1 hybrids."

Belling[3] found on comparing the dried and undried weights of the grain of the F_1 generation hybrid corn with weights of the parents, that the hybrids contained a lower percent of moisture. He concludes from this that the hybrids either were more mature or dried out better than the parents before the drying test was started.

Emerson and East[12] on crossing varieties of corn differing about a month in time of flowering and nearly two months in time of ripening, found that the F_1 hybrids were intermediate in regard to flowering and ripening. In later generations, segregation occurred. In the F_2 generation, plants appeared with a range of variation in earliness from the early parent to, or nearly to the late.

As to the date of maturity of a number of corn crosses, Hayes[17] says: "This is, in general, an intermediate character, although in some cases the cross matured earlier and in other cases later than the parental average."

Wellington[26] found that in the tomato, earliness is slightly increased by crossing. The inheritance in regard to earliness in the F_1 generation was not noted, but from behavior of hybrids in other generations it is probably inherited in an intermediate condition.

The first recorded experiments to study the effect of hybridization in yield of corn were made by Beal[1], beginning in 1876, and these experiments were followed by those of Sanborn (24), McCluer (20), Morrow and Gardner (22), Shull (25), East (11), and Collins (7).

Hartley[13] found that in one instance F_1 generation hybrid seed proved 20 percent more productive than either parent. Hayes and East[15] obtained an increase in yield of the hybrid over the parent in five out of seven crosses. The increase varied from 7 to 44 bushels per acre. Hartley, Brown, et al.[14] obtained increases in yield from some crosses and decreases from some in tests made in Maryland, California, Texas and Georgia. Belling[4] found that the hybrid seed of Mosby pollinated by Cuban yielded over one third more shelled corn to the row than did the pure Cuban or Mosby. Hayes[16] found on crossing varieties of corn that the F_1 generation hybrids yielded, on the average, 91 bushels per acre. The average yield of the parents was 82.3 bushels per acre, or an average increase of 8.7 bushels per acre for the crosses. In conclusion this writer states: "The utilization of F_1 hybrids in corn breeding will materially increase the corn yield. The highest yields of corn will be received from carefully bred selections which, when crossed, prove the most vigorous combinations by actual test."

That the yield from crosses begins to decrease after the first generation is well shown by this writer. One F_1 generation cross yielded at the rate of 105.5 bushels per acre. The F_2 generation of this cross yielded at the rate of 51.5 bushels per acre. The F_1 generation of another cross yielded at the rate of 117.5 bushels per acre, while the F_2 generation of the cross yielded at the rate of 98.4 bushels per acre.

Collins[8] reports that in growing five corn hybrids the average yield was 9 percent greater than the average of the parents. The greatest increase was 34 percent larger than the average of the parents. Four of the five hybrids exceeded either parent in yield. This same writer reports the results of yields from ten sweet corn hybrids. In the F_1 generation, the yield per plant of eight of the ten hybrids exceeded the average of the parents, and in six instances the yield was greater than either parent. The average yield of all hybrids as compared with the average yield of the pure strain showed an increase of 57 percent.

All of the foregoing results of experiments were obtained in the F_1 hybrid generation. However, experiments go to show that there is an increase in size of kernels the same year the cross is made as well as an increase in yield in the F_1 generation. Carrier seems to have been the first to discover and record that there is an immediate increase on crossing strains of corn. Collins[8] makes reference to Professor Carrier's results along with the report of an experiment carried on by himself. Carrier at this time reported an increase of 5 to 18 bushels per acre from cross pollinated strains of corn over the pure strains. His[5] later results of further experiments along this line showed that when different strains of Boone County White were crossed, there was an increased yield of from 7.6 to

31.7 percent of crossed over uncrossed seed. Collins[9] found an increase in size of seed the current year when a variety of maize from China was crossed with an American variety. The crossed seed weighed, on the average, .178 grams and the pure seed .153 grams or an increase in seed weight, due to hybridization, of 16.3 percent. Roberts[23] also reports a noticeable increase in size of hybrid seed over that from the pistillate parent when the Chinese variety of maize used by Collins was pollinated with pollen from an American dent variety, Pride of Saline. In order to obtain further information on the subject, Collins[10] mixed pollen from two varieties of corn and applied it to the silks of one of the varieties, thus obtaining pure and hybrid seed on the same ear. The difference in size of seed produced could be readily noted, as Collins says: "The hybrid and pure seeds from each of the ears, when weighed separately, exhibited such striking differences that it is thought advisable to place the results on record. In every instance the hybrid seed was larger than the pure seed and borne on the same ear, the increase ranging from 3 to 21 percent."

The junior author[28] found that when pollen from two varieties of corn was mixed and applied to the same ear of one of the varieties, in some instances the hybrid seed were larger and in other instances smaller. In 37 crosses, 27 produced an increase in size of hybrid seed varying from .2 to 16.04 percent. In the remaining crosses, there was a decrease ranging from .3 to 13.45 percent. The average percentage of increase in size was 5.93 percent; of decrease, 5.65 percent.

Statement of the Problem

The object of the experiment herein reported is to study the effect of hybridization of varieties of corn on maturity and yield in the F_1 generation.

Materials and Methods Used

In the summer of 1915, crosses were made between Reid's Yellow Dent and Gold Standard as pollen parents, and Boone County White, Shenandoah County White and Johnson County White, as seed parents. Thus there were six crosses made in all.

In the spring of 1916, four series were planted with the five parent varieties and the six hybrids. There were four rows of twenty hills each of each variety in each series, each hill being thinned to two stalks. The same cultivation and fertilization were given to all the series. Daily notes were taken from the time tasseling began until silking was complete. The time of tasseling and silking was obtained for each individual plant, and the time of maturity was secured from each row.

Results of the Experiment

In Table I are presented data showing the number of individuals which tasseled, the number which silked, and the average number of days from planting to tasseling and silking for each of the parent varieties and the six hybrids.

TABLE I.—*Number of Individuals Which Tasseled and Silked, and the Average Number of Days from Planting to Tasseling and Silking for the Parent Varieties and Their Crosses*

Varieties and Crosses	Number of Individuals		Average Number of Days from Planting to	
	Tasseling	Silking	Tasseling	Silking
Reid's Yellow Dent (P_1)	146	149	81.77	89.13
Gold Standard (P_1)	149	151	81.01	90.53
Shenandoah County White (P_1)	155	152	80.07	89.18
Boone County White (P_1)	148	148	84.04	90.66
Johnson County White (P_1)	152	146	84.84	92.06
Shenandoah County White x Gold Standard (F_1)	153	149	76.16	84.76
Boone County White x Gold Standard (F_1)	149	150	82.32	89.57
Johnson County White x Gold Standard (F_1)	155	154	78.10	85.64
Shenandoah County White x Reid's Yellow Dent (F_1)	159	157	78.42	87.45
Boone County White x Reid's Yellow Dent (F_1)	144	141	80.30	88.34
Johnson County White x Reid's Yellow Dent (F_1)	151	147	81.56	90.07

TABLE II.—*Difference in Time of Tasseling and Silking of Hybrid Corn as Compared with Each Parent and the Average of the Latter*

Hybrids	Difference in Time of Tasseling and Silking of the Hybrid as Compared with				Average of Parents	
	Seed Parent		Pollen Parent			
	Tasseling	Silking	Tasseling	Silking	Tasseling	Silking
	Days	*Days*	*Days*	*Days*	*Days*	*Days*
Shenandoah Co. White x Gold Standard	3.91	4.42	4.85	5.77	4.38	5.10
Shenandoah Co. White x Reid's Yellow Dent	1.65	1.73	3.35	1.68	2.50	1.71
Boone County White x Gold Standard	1.72	1.09	–1.31	.96	.21	1.03
Boone County White x Reid's Yellow Dent	3.74	2.32	1.47	.79	2.61	1.56
Johnson County White x Gold Standard	6.74	6.42	2.91	4.89	4.83	5.66
Johnson County White x Reid's Yellow Dent	3.28	1.99	.21	–.94	1.75	.53

In Table II it will be seen that the hybrids tasseled and silked before the seed parent in every case, and before the pollen parent in every instance, save two. The cross, Boone County White x Gold Standard, tasseled 1.31 days later than did the Gold Standard variety. The Johnson County White x Reid's Yellow Dent cross silked .94 days later than did Reid's Yellow Dent. The crosses tasseled and silked before the average of the parents in every case. The increase in earliness of the crosses, Shenandoah County White x Gold Standard and Johnson County White x Gold Standard, as compared with the average of the parent, is marked. The increase in case of the other hybrids over the average of their parents is not quite so pronounced.

In Table III are presented data showing the average number of days from planting to harvesting for each of the parent varieties and their crosses.

TABLE III.—*Average Number of Days from Planting to Harvesting*

Varieties and Crosses	Average Number of Days
Reid's Yellow Dent (P_1)	$139\frac{1}{2}$
Gold Standard (P_1)	$141\frac{3}{4}$
Shenandoah County White (P_1)	$140\frac{1}{2}$
*Boone County White (P_1)	$144\frac{2}{3}$
Johnson County White (P_1)	$143\frac{3}{4}$
Shenandoah County White x Gold Standard (F_1)	$135\frac{1}{2}$
Boone County White x Gold Standard (F_1)	$140\frac{3}{4}$
Johnson County White x Gold Standard (F_1)	$138\frac{1}{4}$
Shenandoah County White x Reid's Yellow Dent (F_1)	$138\frac{1}{4}$
Boone County White x Reid's Yellow Dent (F_1)	$141\frac{3}{4}$
*Johnson County White x Reid's Yellow Dent (F_1)	$140\frac{2}{3}$

*Of the four rows planted, one row was not mature when harvested.

TABLE IV.—*Difference in Days to Harvesting of Hybrids as Compared with Each Parent and the Average of the Latter*

Hybrids	Difference as Compared with		Average of Parents
	Seed Parent	Pollen Parent	
Shenandoah County White x Gold Standard	5	$6\frac{1}{4}$	$5\frac{5}{8}$
Shenandoah County White x Reid's Yellow Dent	$2\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$
Boone County White x Gold Standard	$3\frac{11}{12}$	1	$2\frac{11}{24}$
Boone County White x Reid's Yellow Dent	$2\frac{11}{12}$	$-2\frac{1}{4}$	$\frac{1}{3}$
Johnson County White x Gold Standard	$5\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$
Johnson County White x Reid's Yellow Dent	$3\frac{1}{12}$	$-\frac{1}{6}$	$\frac{23}{24}$

The data in Table IV agrees with that in Table II in that the two crosses that gave marked earliness, as compared with the average of their parents, in regard to tasseling and silking, also show pronounced earliness as to final maturity. In Table IV it will be seen that the crosses, in every instance, matured before the seed parents. On the other hand, as compared with the pollen parents, four hybrids matured earlier and two later. In the two instances of later maturity of the hybrids, the pollen parent was Reid's Yellow Dent, which, as shown in Table III, is the first of the parental varieties to mature. In every instance the hybrids matured earlier, as compared with the average time of maturity of both parents.

The hybrid, Shenandoah County White-Gold Standard, matured 5 days before the seed parent and 6¼ days before the pollen parent. The seed parent was only one day later and the pollen parent 2¼ days later in maturing than was Reid's Yellow Dent. The hybrids obtained when this latter variety was used as the pollen parent were later in maturing than the pollen parent, but earlier than the seed parent.

Boone County White and Johnson County White are later in maturing than Shenandoah County White. However, when the two former varieties are used as seed parents with either Gold Standard or Reid's Yellow Dent as pollen parents, hybrids are produced whose earliness in maturity is not as marked as when Shenandoah County White is used as the seed parent with these varieties as pollen parents.

The corn growers who furnished the Shenandoah County White and Gold Standard seed, practice closer inbreeding than do the breeders which furnished the seed of the other varieties. From a study of Table IV it seems that the varieties which have been most closely inbred, when crossed, produce hybrids of earlier maturity than varieties which have not been as closely inbred.

In Table V are presented data showing the yield per acre of shelled corn for the hybrids and the parent varieties, with the exception of two hybrids which were accidentally mixed before weighing.

Table V.—*Yield of Grain in Bushels per Acre*

Varieties and Crosses	Yield
Reid's Yellow Dent (P_1)	84.84
Gold Standard (P_1)	69.98
Shenandoah County White (P_1)	56.28
Boone County White (P_1)	61.58
Johnson County White (P_1)	54.79
Shenandoah County White x Gold Standard (F_1)	64.06
Boone County White x Gold Standard (F_1)	——
Johnson County White x Gold Standard (F_1)	75.92
Shenandoah County White x Reid's Yellow Dent (F_1)	——
Boone County White x Reid's Yellow Dent (F_1)	68.60
Johnson County White x Reid's Yellow Dent (F_1)	70.47

Comparing the yield and time of maturity of the hybrids Shenandoah County White x Gold Standard and Johnson County White x Gold Standard, we find that the earliness in maturity and increase in yield is very marked. The first named hybrid matured 5 days before the seed parent and 6¼ days before the pollen parent. This hybrid yielded 5.92 bushels of grain per acre less than the pollen parent, but 7.78 bushels more than did the seed parent. The last named hybrid matured 5½ days before the seed parent and 3½ days before the pollen parent. The hybrid yielded 5.94 bushels of grain per acre more than the pollen parent and 21.13 bushels more than did the seed parent. The hybrids, Boone County White x Reid's Yellow Dent, and Johnson County White x Reid's Yellow Dent did not mature practically any earlier, on the average, than did the parents. However, both of these hybrids yielded more than the seed parents, but less than the pollen parents.

In Table VI are presented data showing the percentage of increase or decrease in yield of grain of the hybrids as compared with the parents and the average of the latter.

Table VI.—*Percentage of Increase in Yield of Hybrids over the Parents and Average of the Latter*

Hybrids	Increase over		Average of Parents
	Seed parent	Pollen parent	
	Percent	*Percent*	*Percent*
Shenandoah Co. White x Gold Standard	13.82	–9.24	1.47
Johnson County White x Gold Standard	38.57	8.49	21.70
Boone County White x Reid's Yellow Dent	11.40	–23.67	–6.72
Johnson County White x Reid's Yellow Dent	28.62	–20.39	.938

In Table VI it is shown that in every case the hybrids yielded more than the seed parent. This increase ranged from 11.40 percent to 38.57 percent. In three cases the pollen parent yielded more than the hybrids and in one case the reverse was true. The decrease varied from 9.24 percent to 23.67 percent. As compared with the average of the parents, the hybrids produced a larger amount of grain per acre in three instances, and in one case there was a decrease. The increase ranged from .938 percent to 21.7 percent.

CONCLUSIONS

There exists marked earliness in time of maturity of some hybrids as compared with their parents. In other hybrids, the increase is not marked. However, in every case, the hybrids matured earlier than their parents, when an average of the time of maturity of the latter was taken as a basis of comparison.

Along with increase in earliness there is also an increase in yield in the F_1 hybrids.

The increase in earliness and yield of the cross, Johnson County White x Gold Standard, is very marked.

BIBLIOGRAPHY

1. Beal, W. J.—Mich. Bd. Agr. Rept., 1876, p. 206; 1877, p. 50; 1878, p. 450; 1880, p. 288; 1881-82, p. 136.
2. Belling, John—Fla. Agr. Exp. Sta. Rept., 1910, pp. 79-91; 1911, pp. 82-104; 1912, pp. 115-127; 1913, pp. 112-130; 1914, pp. 81-105.
3. Belling, John—"Corn Crosses." Fla. Agr. Exp. Sta. Report 1912, pp. 127-129.
4. Belling, John—"Hybrid Corn." Fla. Agr. Exp. Sta. Press Bulletin **196**. 1912.
5. Carrier, Lyman—"The Immediate Effect of Crossing Varieties of Corn." Va. Agr. Exp. Sta. Bulletin **202**. 1913.
6. Castle, W. E.—"Genetics and Eugenics." p. 299. Harvard University Press, Cambridge, Mass. 1916.
7. Collins, G. N.—"The Value of First Generation Hybrids in Corn." U. S. D. A., B. P. I. Bulletin **191**. 1910.
8. Collins, G. N.—"Increased Yields of Corn from Hybrid Seed." U. S. D. A. Yearbook. pp. 319-328. 1910.
9. Collins, G. N.—"A New Type of Indian Corn from China." U. S. D. A., B. P. I. Bulletin **161**. 1909.
10. Collins, G. N., and Kempton, J. H.—"Effects of Cross-Pollination on the Size of Seed in Maize." In Miscellaneous Papers, U. S. D. A., B. P. I. Circular **124**. 1913.

11. East, E. M.—"The Distinction Between Development and Heredity in Inbreeding." American Nat. **43**: 178-179. 1909.
12. Emerson, R. A., and East, E. M.—"The Inheritance of Quanitative Characters in Maize." Neb. Agr. Exp. Sta. Research Bulletin **2**. 1913.
13. Hartley, C. P.—"Have You a More Productive Corn Than First Generation Cross No. 182?" U. S. D. A., B. P. I. Corn Investigations, p. 4. 1911.
14. Hartley, C. P., Brown, E. B., et al.—"Cross-breeding Corn." U. S. D. A., B. P. I. Bulletin **218**. 1912.
15. Hayes, H. K., and East, E. M.—"Improvement in Corn." Conn. Agr. Exp. Sta. Bulletin **168**. 1911.
16. Hayes, H. K.—"Methods of Corn Breeding." American Breeders' Magazine **3**: 99-108. 1912.
17. Hayes, H. K.—"The Corn Plant and Seed Selection." Conn. State Report. pp. 353-384. 1913.
18. Keeble, F., and Pellew, C.—"The Mode of Inheritance of Stature and of Time of Flowering in Peas (Pisum sativum)." Journal Genetics **I**: 47-56. 1911.
19. Love, H. H.—"The Relation of Seed Ear Characters to Earliness in Corn." Ann. Report American Breeders' Association, 1911-12. Vols. 7-8. p. 334. 1912.
20. McCluer, G. W.—"Corn Crossing." Ill. Agr. Exp. Sta. Bul. **21**. 1892.
21. Moore, R. A., and Stone, A. L.—"Experiments with Grains and Forage Plants." Wis. Agr. Exp. Sta. Ann. Rept. p. 251. 1906.
22. Morrow, G. E., and Gardner, F. D.—"Field Experiments with Corn." Ill. Agr. Exp. Sta. Bulletin **25**. 1893.
23. Roberts, H. F.—"First Generation Hybrids of American X Chinese Corn." Ann. Report American Breeders' Association. 1911-12. Vols. 7-8, p. 374. 1912.
24. Sanborn, W. J.—Maine Bd. Agr. Report, 1889-90. p. 78. 1890.
25. Shull, G. H.—"A Pure Line Method of Corn Breeding." Ann. Report American Breeders' Association. **5**: 53-54. 1909.
26. Wellington, Richard—"Influence of Crossing in Increasing the Yield of the Tomato." N. Y. Agr. Exp. Sta. Bulletin **346**. 1912.
27. Williams, C. B., and Etheridge, W. C.—"Characters of the Corn Plant Associated with Yield and Factors Which Influence Them." Ann. Report American Breeders' Association. **6**: 237-244. 1911.
28. Wolfe, T. K.—"Further Evidence of the Immediate Effect of Crossing Varieties of Corn on the Size of Seed Produced." Journal of American Society of Agronomy. **7**: 265-272. 1915.

AVAILABILITY OF GROUND LIMESTONE OF DIFFERENT DEGREES OF FINENESS

By T. B. Hutcheson, T. J. Murray and T. K. Wolfe

"How fine should limestone be ground for agricultural purposes?" is a question often asked by farmers. Usually the reply is: For limestone of equal purity, the finer the particles the more valuable the material. This reply is based more upon theoretical assumptions than upon results of actual experiment. The finer the rock is ground the greater its cost, thus it is practical to determine to what degree of fineness limestone should be ground to give the most profitable results.

Review of Literature

Little exact experimental data bearing on the subject are found. However, in many instances marked benefit has been obtained from the application of limestone. Following is briefly given a review of some experiments with direct bearing on the availability of limestone of different degrees of fineness.

H. Von Feilitzen (2) found on applying slaked lime and powdered limestone of different fineness on peat soils low in lime, but highly fertilized with potash and phosphoric acid, that the yields of barley were increased, as the fineness of either form of lime was increased. However, there was one exception; viz., the next to the finest grade of slaked lime gave somewhat better results than the finest.

Thomas and Frear (3) show that the yield of clover increases as the fineness of the limestone applied increases. In the following table the highest yield is taken as 100 per cent.

Relative Yield of Tops and of Roots of Clover from Application of Limestone Different Fineness

Limestone	Tops	Roots
Mesh		
100	100	100
80	94.7	89.7
60	85.2	89.5
40	66.5	74.8
20	11.9	25.2
Check	....	....

In conclusion these authors say: "On silty loam and on soil of heavier texture, on lands where soil acidity is the chief factor limiting clover production, crushed limestone used for amendment should be at least 60-mesh in fineness of pulverization."

White (4) shows in the following table that the amount of nitric nitrogen increases with the increase in fineness of the limestone applied.

The Amount of Nitric Nitrogen According to Fineness of Limestone

Limestone	Nitric Nitrogen
Mesh	*Parts per million*
100	37.98
60	37.57
20	28.57
8	22.09
Check	20.76

At the Maryland Station (1) it was found that ground limestone varied according to its fineness in its solubility in water, in water charged with carbon dioxide and in a soil solution. The authors state: "In order to furnish as much soluble calcium, by the use of ground stone * * * to a soil as calcium oxide will furnish, the stone * * * must be ground so that at least 90 percent will pass an 80-mesh sieve." Concluding they say: "Better results will be obtained by using calcium oxide (lime) or limestone * * * ground to pass an 80-mesh sieve than by using a coarser grade of limestone. * * * However, marked increases will be noted by the use of large quantities of coarse material, due in a large measure, to the fine material that is found in any limestone after it has been ground."

Statement of Problem

The object of this experiment was to make a study of the effect that limestone, when ground to different degrees of fineness and applied to soil, had on crop yield, on nitrate formation, and on the number of bacteria.

Materials and Methods

Part of a middle bed in the green house was partitioned into five divisions, and filled with Pulaski red shale soil to a depth of about 18 inches. This soil is usually low in organic matter, phosphorus and lime, but rather

high in potassium. It was found that this particular soil required 2160 pounds of calcium oxide to neutralize the acidity, assuming the weight of the tillable portion of an acre to be 2,000,000 pounds.* The limestone used was guaranteed to contain 90 percent calcium carbonate. This material was applied at a rate sufficient to give an equivalent of 2160 pounds of calcium oxide per acre. Fertilizer was applied to each plat at the following rate per acre: Acid phosphate (16% P_2O_5) 1000 pounds and 500 pounds each of dried blood (16% ammonia) and sulphate potash (50.47% K_2O). In addition, plat 1 received limestone ground to a fineness of 10 to 20-mesh; plat 2, limestone all of which passed through a 100-mesh sieve; plat 4, limestone of 40 to 60-mesh; plat 3, equal parts of limestone of the three different degrees of fineness; plat 5 no limestone. By 10 to 20-mesh limestone is meant limestone that will pass through a sieve containing 10 meshes to the linear inch, but not through one containing 20.

Rape was planted January 20, 1917, and the crop harvested on April 9. The first two seedings failed to germinate uniformly and the seeding which produced this crop was made on January 31. After the fertilizers and limestone had been applied, but before the seed were planted, two areas, each seven inches in diameter, were enclosed in each plat by driving two stove pipes in the soil to a depth of 12 inches. Nitrate analyses and bacterial counts were made at the beginning and monthly thereafter from both the enclosed and unenclosed areas.

Results of the Experiment

In Table I are presented data showing the yield of moisture-free rape from each plat, and the relative yields in percent.

TABLE I.—*Yields of Rape in Grams and Relative Yields in Percent*

PLAT No.	LIMESTONE	WEIGHT PER PLAT (Moisture-free)	RELATIVE YIELDS
	Mesh	*Grams*	*Percent*
2	100	110.26	100
3	Equal parts 10-20; 40-60; 100	97.38	88.32
4	40-60	85.12	77.20
1	10-20	58.9	53.42
5	Check	47.51	43.09

*The writers wish to express their thanks to Dr. W. B. Ellett for making the determination of the lime requirement of the soil used in this experiment.

It may be seen from the foregoing table that the plat which received the finest ground limestone produced approximately 12 percent higher yield than the plat which received the mixed limestone; 23 percent greater yield than the intermediate limestone plat; 47 percent greater yield than the. coarse limestone plat; and 57 percent greater than the check plat.

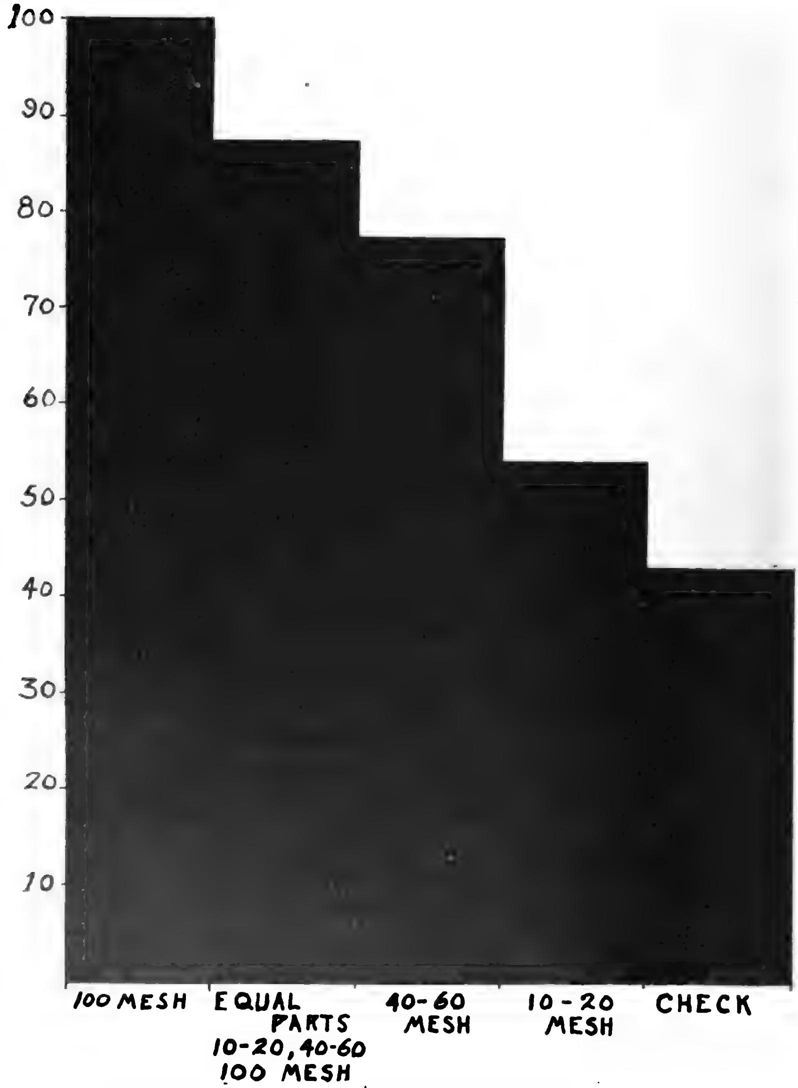


FIG. 1—A graphic representation of relative yields from applications of limestone of different fineness. The yield from an application of limestone of 100-mesh fineness was taken as a standard and is represented by 100 percent; then by comparison limestone of mixed fineness gave 88.32 percent; 40-60-mesh limestone 77.2 percent; 10-20-mesh limestone 53.42 percent; check plat 43.09 percent.

In Table II are presented data showing milligrams of nitrate nitrogen per gram and total amount in crop from each plat.

TABLE II.—*Total Nitrogen in Milligrams per Gram of Crop and in Total Crop*

LIMESTONE *Mesh*	TOTAL NITROGEN PER GRAM (Milligrams)	TOTAL NITROGEN IN CROP (Milligrams)
100	36.85	4063.08
Equal parts 10.20; 40-60; 100	37.32	3634.22
40-60	38.72	3295.85
10-20	39.33	2316.54
Check	44.23	2101.37

It may be seen in Tables I and II that as the crop yield increases the total amount of nitrogen removed increases. The plants grown on the plats which received coarse ground limestone and on the check plat, contain the highest percentage of nitrogen. As shown in Table II, the plants from the check plat contained the highest percentage of nitrogen. From a study of Tables II and III, it does not seem that nitrogen is the limiting factor in the production of this soil. Liberal quantities of phosphorus and potassium were applied and it is not likely that either of these elements are limiting factors in the production of maximum crop yields. It appears that the need of lime is the chief requirement of this soil. The beneficial effect of lime may be either physical, chemical or biological, or all three. The soil bakes easily and requires frequent cultivations for the plants to make proper growth. From the results so far obtained the greatest benefits of liming are due to the correction of acidity, increasing the number of bacteria, and the improvement of the physical condition of the soil. To obtain maximum yields on this type of soil, lime should be applied in a readily available form, together with liberal quantities of nitrogen, phosphorus and, probably, potash. Chemical analyses show that this soil is low in nitrogen and phosphorus, but comparatively high in potassium.

In Table III are presented data showing the amount of nitrates formed at different periods during the experiment in the enclosed and unenclosed areas.

TABLE III.—*Milligrams of Nitrate Nitrogen per 100 Grams of Soil*

LIMESTONE *Mesh*	FEB. 20 UNENC. AREA	FEB. 20 ENCL'D AREA	MARCH 20 UNENC. AREA	MARCH 20 ENCL'D AREA	APRIL 9 UNENC. AREA	APRIL 9 ENCL'D AREA	AVG. OF ANALYSES UNENC. AREA	AVG. OF ANALYSES ENCL'D AREA
100	2.75	2.87	2.51	2.85	1.64	3.16	2.30	2.96
Equal parts 10-20; 40-60; 100	2.86	2.70	2.17	2.57	1.86	2.11	2.30	2.46
40-60	2.64	2.81	2.56	2.52	2.00	2.61	2.40	2.65
10-20	2.54	2.75	2.57	2.68	2.50	1.95	2.54	2.46
Check	2.64	2.75	2.51	2.23	1.70	2.11	2.25	2.36

An analysis of the soil at the beginning of the experiment showed 2.4 milligrams of nitrate nitrogen per 100 grams of soil.

Data are presented in Table IV showing the number of bacteria as counted on beef peptone agar and on synthetic agar at different periods during the experiment in the enclosed and unenclosed areas.

TABLE IV.—*Number of Bacteria* per Gram of Soil at Different Periods*

LIMESTONE *Mesh*	FEBRUARY 20				MARCH 20				APRIL 9			
	BEEF PEPTONE†		SYNTHETIC‡		BEEF PEPTONE		SYNTHETIC		BEEF PEPTONE		SYNTHETIC	
	Unenclosed Area	Enclosed Area	Unenclosed Area	Enclosed Area	Unenclosed Area	Enclosed Area	Unenclosed Area	Enclosed Area	Unenclosed Area	Enclosed Area	Unenclosed Area	Enclosed Area
100	7,400	6,100	6,530	4,050	5,000	5,560	4,000	7,000	860	820	830	880
Equal parts 10-20; 40-60; 100	4,190	3,100	3,750	3,130	4,100	900	4,850	2,250	215	310	440	340
40-60	400	1,320	250	760	750	510	1,000	1,330	390	250	311	290
10-20	240	210	170	150	860	640	1,090	990	174	200	340	370
Check	250	200	160	120	710	365	890	620	280	250	400	400

*Average of Counts from Table IV**

LIMESTONE *Mesh*	BEEF PEPTONE		SYNTHETIC	
	UNENCLOSED AREA	ENCLOSED AREA	UNENCLOSED AREA	ENCLOSED AREA
100	4,420	4,160	3,786	3,976
Equal parts 10-20; 40-60; 100	2,835	1,436	3,013	1,906
40-60	513	693	520	793
10-20	424	350	533	503
Check	413	271	483	380

*NOTE—Last three ciphers omitted from figures.

†H_2O	1,000	grams	‡H_2O	1,000.00	grams
Peptone	10	"	Dextrose	10.00	"
Salt	5	"	K_2HPO_4	.50	"
Liebig Extract	3	"	$MgSo_4$	.20	"
Agar agar	15	"	Peptone	.05	"
			Agar agar	15.00	"

At the beginning of the experiment, the counts on beef peptone agar showed 500,000 bacteria, on synthetic agar 300,000 bacteria per gram of soil.

It may be seen in Table III that the average of the analyses shows that the amount of nitrates is higher in the enclosed than in the unenclosed area with exception of the plat to which 10-20 mesh limestone was applied. The larger amounts in the enclosed area are due to the absence of plants, which when present assimilate a portion of the nitrates formed. The smallest amount of nitrates was formed in the check plat in both the enclosed and unenclosed areas. The plat receiving the finest limestone produced the largest amount of nitrates in the enclosed area. However, in the unenclosed area on this plat, the production of nitrates was practically the same as that of the plat which received the mixed fineness of limestone and was lower than the other two limestone plats. On the unenclosed area of the plats where limestone had been applied, the nitrate accumulation decreases as the crop increases. The average of the bacterial count in Table IV shows that the number of bacteria increased as the fineness of the limestone applied increased.

SUMMARY

The results of this experiment show that the yield of rape and the number of bacteria increased as the fineness of limestone increased. The effect of limestone on nitrate production showed some variation. However, the enclosed areas in the plat which received the finest grade of limestone contained the highest amount of nitrates, and the enclosed areas of the check plat the least amount.

It seems that when rape is grown on this type of soil the chief limiting factor in maximum production is lime.

BIBLIOGRAPHY

1. Broughton, L. B., Williams, R. C., and Frazer, G. S.—Test of the Availability of Different Grades of Ground Limestone. Md. Agr. Exp. Sta. Bul. **193**. 1916.
2. Feilitzen, H. Von—On the Influence of the Fineness of Lime on its Action as an Amendment to Peat Soils Low in Lime. Svenska Mosskulturför. Tidskr. **24**. No. 2, pp. 95-98. 1910. Experiment Station Record **23**: 426-427.
3. Thomas, Walter, and Frear, William—Experiments to Determine the Influence of the Fineness of Subdivision and Richness in Magnesium Carbonate of Crushed Limestone used for Amendment of Acid Soils. In Ann. Rept. Pa. State College, 1912-13. pp. 213-314.
4. White, J. W.—Nitrification in Relation to the Reaction of the Soil. In Ann. Rept. Pa. State College, 1913-14. p. 79.

DUSTING FOR CEDAR RUST[1]

By F. D. Fromme and H. E. Thomas[2]

The recent revival of interest in the dry method of application of fungicides and insecticides has been brought about in large measure through the introduction of finely ground materials which have greater covering power and greater efficiency than the comparatively coarsely ground materials formerly employed in similar work. A finely ground sulphur, "superfine", has been used by Blodgett[3] and by Reddick and Crosby[4] successfully for the control of apple scab and in combination with dry arsenate of lead for codling moth. Stewart[5] has used the same materials in controlling various leaf diseases of nursery stock, cherry, horse chestnut, currant, rose, plum and quince. Smith[6] has used sulphur dust for asparagus rust, Blodgett[7] for the hop mildew, and Reddick[8] for the powdery mildew of grapes.

The writers[9] have reported the successful use of a dusting mixture containing copper for late-blight of tomato.

On account of the variability in the infection periods of the cedar-rust disease of apples (*Gymnosporangium juniperi-virginianae*) a fixed liquid spray schedule, as used in the cedar infested regions of Virginia, is not commonly effective as a control. The possibility of effective control of this disease by liquid applications of Bordeaux mixture and lime-sulphur has been demonstrated by various workers,[10-12] but it has been evident that applications to be effective must be made in advance of periods of sporidial dispersal. These periods follow rains of considerable duration, four or six hours being normally the minimum, during the period of infection from April 15 to about June 1. Three periods of sporidial discharge commonly occur during this period of infection, the time of each being dependent on climatological factors. If it were possible to predict the time

[1]Paper No. 49 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agricultural Experiment Station.

[2]The experiment was carried on in co-operation with Prof. G. C. Starcher, formerly of the Horticultural Department, to whom we are indebted for suggestions and assistance in the earlier stages of the work.

[3]Blodgett, F. M.—New York (Cornell) Exp. Sta. Bul. 340. 1914.

[4]Reddick, Donald, and Crosby, C. R.—New York (Cornell) Exp. Sta. Bul. 354. 1915; also Bul. 369. 1916.

[5]Stewart, V. B.—New York (Cornell) Exp. Sta. Cir. 32. 1916; also Bul. 385. 1917.

[6]Smith, R. E.—California Exp. Sta. Bul. 165. 1905.

[7]Blodgett, F. M.—New York (Cornell) Exp. Sta. Bul. 328. 1913.

[8]Reddick, Donald—Int. Cong. Vit. 1915: 117-125. 1916.

[9]Fromme, F. D., and Thomas, H. E.—Virginia Exp. Sta. Bul. 213. 1916.

[10]Bartholomew, E. T.—Phytopathology 2: 253-257. 1912.

[11]Giddings, N. J., and Neal, D. C.—Phytopathology 2: 258. 1912.

[12]Reed, H. S., Cooley, J. S., and Crabill, C. H.—Virginia Exp. Sta. Bul. 203. 1914.

of rains of sufficient duration to produce sporidial discharge early enough to enable the orchardist to spray the trees exposed to infection, the practical control of cedar-rust should be readily effected. The above is obviously impracticable in commercial work and cedar-rust control work in the state has become chiefly a matter of eradication of cedars.

It has seemed probable that the difficulties involved in liquid spraying might be overcome by the substitution of the dusting method. The rapidity of the dust applications, thirty or forty acres may be covered with a dusting machine in a day, should allow for the protection of considerable areas on short notice in advance of or during light rainfall, and the lightness of the outfit should permit its use immediately following rains if protection could be secured in this way. These ideas were tested during the spring of 1916, but no control of cedar rust infection was obtained.

Details of Experiments

The plats were located in a 17 acre orchard of mixed varieties of apples on the farm of Mr. G. F. Blandy[13], White Post, Clarke County, Virginia. The orchard bordered on the lawn which contained about 250 red cedar trees averaging 40 or 50 feet in height all well covered with viable cedar-rust galls. The orchard was planted in 1904 and the trees nearest the cedars were considerably stunted from repeated attacks of rust. Five plats were provided, each consisting of three rows of twenty trees, so located as to be under equal conditions of exposure to infection. Tree No. 1 in each row bordered on the block of cedars. Three of the plots (I, III, and IV) received applications of a dust mixture in the ratio of 75 pounds of sulphur[14] to 25 pounds of hydrated lime, with the addition of 20 pounds of arsenate of lead for codling moth in two applications. The remaining plats were planned to serve as checks, one (II) to receive the regular lime-sulphur liquid applications, the other (V), to receive arsenate of lead, with hydrated lime as a filler, for codling moth. The three dust plats were planned to test the efficiency of dust applications made immediately before each important rain (plat IV), immediately after each rain causing sporidial discharge (plat III), and on the regular spray schedule (plat I), i. e. first application when buds show pink, second immediately following the fall of petals, third and fourth at intervals of ten to fourteen days. The materials used and dates of application are shown in Table I.

[13]We are indebted to Mr. G. F. Blandy and Mr. C. E. Koontz for hearty co-operation in the work.

[14]The sulphur "superfine" was supplied by the Union Sulphur Company of New York; the hydrated lime by the Security Cement and Lime Company, Hagerstown, Md.; and the arsenate of lead by the Corona Chemical Company, Milwaukee, Wis.

FIG. 1—Dusting apple trees at White Post, showing how the dust cloud sifts through the foliage.

TABLE I.—*Data of Applications on Plats in Dusting Experiment*

PLAT No.	TREATMENT	DATE	MATERIALS S. L. A.†	QUANTITY (pounds)	TIME (minutes)
I	Dust on fixed schedule	Apr. 21	75-25	60	45
		May 4	75-25-20	60	30
		May 18	75-25	80	45
		May 29	75-25-20	60	28
II	Lime-sulphur on fixed schedule*	May 12	Lime-sulphur summer strength plus arsenate of lead		
III	Dust after rains	Apr. 22	75-25	60	40
		May 5	75-25-20	70	40
		May 17	75-25	65	35
		May 29	75-25-20	55	28
IV	Dust before rains	Apr. 22	75-25	65	30
		May 4	75-25-20	55	25
		May 20	75-25	65	25
		May 30	75-25-20	55	24
V	Check Insecticide only	May 12	00-85-15	60	30
		May 30	00-85-15	55	22

*Owing to the pressure of other work, this plat received but one spray and that after the two most important periods of sporidial discharge. It serves practically as an unsprayed check.
†S—sulphur; L—hydrated lime; A—arsenate of lead.

The dust applications were made from one side of the trees with a light power dusting rig, figs. 1 and 2. A mechanical dust mixer was used in preparing the various mixtures. No difficulty was experienced in making dust applications, even following periods of heavy rainfall. Apparently considerable quantities of the dust were washed off by the heavy rainfall and this was found to be true on microscopical examination. While the presence of moisture on the leaves probably held more of the dust than the dry surfaces, it was possible to provide a heavy even coating when the leaves were dry. No foliage or fruit injury from the dust mixture was apparent. An average of 62 pounds of the dust mixtures per plat, or about 1 pound per tree, was used for each application and the time required for each application averaged 32 minutes per plat or about one-half minute per tree.

FIG. 2—Another view of the duster in operation.

Three periods of sporidial discharge occurred during the season. The first came on April 22, following a rainfall of .67 inches; the second on May 5, following a rainfall of 1.41 inches; and the third on May 16, after a rainfall of .62 inches. Owing to other factors, lack of wind, unfavorable temperature, etc., none of these produced a heavy infection. The occurrence of periods of sporidial discharge was determined by exposing spore traps under the cedars and in the orchard.

The degree of infection was determined by counts of rust spots on all leaves of ten terminal twigs of each count tree. Only a few varieties were found to be represented under equal conditions of exposure in all plats. The counts obtained on Stark and Ben Davis on May 31 are shown in Table II. Practically all of the infection on these trees came from the second sporidial discharge on May 5.

TABLE II.—*Average Number of Rust Infections per Twig on Count Trees*

Variety	Row No.	Plat No. I	II	III	IV	V
Stark	9	65	64	91	45	75
Ben Davis	20	21	17	10	14	21

To the eye no difference in the degree of infection on the same variety was apparent and this is shown in the counts. No constant decrease in infection could be found on any of the plats receiving dust applications over the checks. Two count trees of Snow in plats II and III in the third row from the cedars, gave an average infection of 205 spots per twig in plat III, dusted immediately following rainfall, and 190 spots per twig in plat II, which served practically as an unsprayed check; a very close approximation.

We are unable to account for the complete failure of all of the dust applications in preventing cedar rust infection. The applications of April 21 and May 4 on plat I, both of which came the day preceding a sporidial discharge, should have been most effective theoretically. Plat IV also received two applications immediately before periods of sporidial discharge. Our data indicates that infection from germinating sporidia may become established within four to six hours after sporidial discharge. At least two of the applications on plat III, dusted immediately after rains, were made before infection could have become established, but the dust probably did not go into solution rapidly enough to inhibit germination and infection.

DUSTING FOR PEACH SCAB[1]

By H. E. Thomas

Although considerable experimental data is available to show the comparative value of dust applications for the control of apple diseases, but little work has been reported on the use of the dry materials for diseases of the peach. Martin[2] records a gain in dusting with sulphur over liquid applications of self-boiled lime-sulphur in the control of peach scab and curculio. Considerable foliage injury was obtained, however, with the dry material which more than offset the slight gain.

A preliminary trial of a dry lime and sulphur mixture on peaches was made in the experimental orchard at Blacksburg during the season of 1916. Two plats were provided, the dusted plat consisting of two rows of 30 seven-year-old trees of mixed varieties, and a single adjoining row, which received no applications,[3] serving as a check.

The dust mixture contained 25 parts of hydrated lime and 75 parts of "superfine" sulphur. The applications were made with a power dusting rig, from both sides of the row, on the following dates: June 29, July 14, July 31, and August 14. The quantity of the dust mixture used averaged about 0.8 pounds per tree for each application.

The dusting rig was not available for use prior to June 29, and this permitted the scab fungus (*Cladosporium carpophilum* Thuem.) to become well established before the control work was begun. While no other disease developed in any considerable amount on the plats, the seasonal conditions were especially favorable for scab development. The rainfall for the months of June, July and August was 17.28 inches as compared with 12.31 inches for the same period in 1915, and 14.54 inches in 1914.

The dust mixture adhered especially well to the velvety-tomentose surface of the peach fruit and but little apparently was removed by rainfall. The smooth foliage, on the other hand, did not retain the material in perceptible amounts. No foliage or fruit injury was apparent.

Owing to the small yield of many of the trees an exact estimate of the degree of control was made on one variety only, represented by one tree in each plat. The results obtained here are, however, a fair expression of the general condition of the dusted and check plats. The trees used for counts were of a medium sized, late-ripening variety, the name of which was not determined. Counts were made on September 1 of all fruits and

[1]Paper No. 50 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agricultural Experiment Station.

[2]Martin, G. W.—Ann. Rept., New Jersey Exp. Sta. 1914: 489-492. 1915.

[3]All trees received the dormant spray of lime-sulphur in March.

the total number of clean and scabbed fruits was obtained. To obtain a more detailed expression the scabbed lot was separated into two lots, heavy scab and light scab, the line of separation for heavy scab being placed at the point where the scab spots were sufficiently numerous to begin to coalesce. A statement of the results is found in Table I.

TABLE I.—*Yield of Clean and Scabbed Fruits on Peach Trees from Dusted and Check Plats*

		Heavy Scab	Light Scab	Total Scab	Clean
Number of fruits	Dusted tree	1	142	143	526
	Check tree	541	197	738	3
Percent of infection	Dusted tree	0.1	21.3	21.4	78.6
	Check tree	73.0	26.6	99.6	0.4

The efficiency of the dust applications is shown to be strikingly high in these figures considering that scab infection had become well established before the first application. The mixture not only prevented the spread of the scab to non-infected fruit, as shown by the high percent (78.6) of clean fruit on the dusted tree compared with the extremely low percent (0.4) of clean fruit on the check, but also checked the development of the disease on infected fruit or prevented reinfection. This fact is shown in the relative degree of infection, 73.0 percent of the fruit on the check tree being classed under heavy scab, while only 0.1 percent of that on the dusted tree fell in this class. All fruit harvested from the two count trees is shown in the photographs (figs. 1 and 2) with the exception of the one heavily scabbed fruit from the dusted tree and the three clean fruits from the check tree.

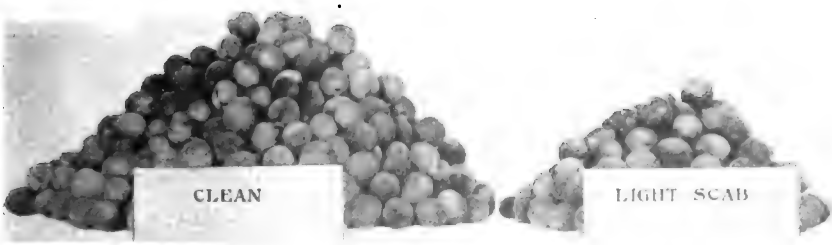


FIG. 1—Yield of fruit from peach tree in the plat dusted four times with dry lime and sulphur mixture. Pile on the left free from scab, that on the right slightly scabbed. One heavily scabbed fruit not shown.

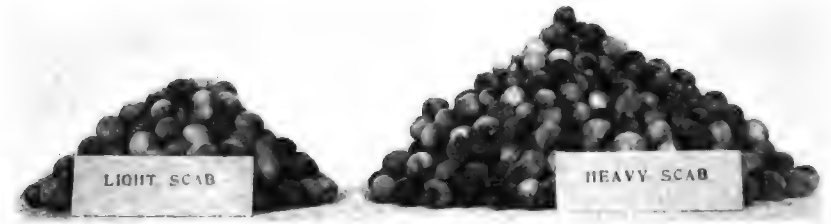


FIG. 2—Yield of fruit from peach tree in the check plat. Pile on the left slightly scabbed, that on the right heavily scabbed. Three clean fruits not shown.

The indications from these tests are that the application of sulphur in the dry form with hydrated lime as a filler, should prove a practical control for peach scab. Tests on the value of the dusting method for the control of other fungous and insect pests of the peach should yield promising results.

PLANT DISEASES IN VIRGINIA IN 1915 AND 1916[1]

By F. D. Fromme

Beans

Stem Crack (*Rhizoctonia solani Kühn*).—Snap beans (*Phaseolus vulgaris*) from Henrico County were affected at the soil line with pronounced lesions which resulted in stem cracks and falling over of the plants, as

Fig. 1—Stem crack of snap beans.

shown in fig. 1. The report stated that practically all plants in one patch were affected. *Rhizoctonia solani* was obtained in culture and used for successful stem inoculations.

Beans, Lima

Downy Mildew (*Phytophthora phaseoli* Thaxter).—This disease which is essentially northern in occurrence appeared in gardens at Blacksburg during the late summer of 1916. Pod infection of the lima bean (*Phaseolus lunatus*) (fig. 2) was common and the loss of crop almost total. Sea-

[1]Paper No. 48 from the Laboratories of Plant Pathology and Bacteriology, Virginia Agricultural Experiment Station.

sonal conditions were unusually favorable for the development of Phytophthoras, the rainfall for the months of June, July and August being 17.28 as compared with 12.31 for the same period in 1915 and 14.54 in 1914.

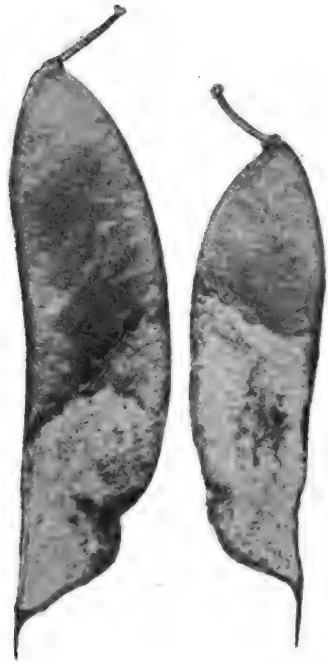


FIG. 2—Lima bean pods affected with downy mildew.

Beets

Root Knot.—This disease is caused by minute parasitic worms or nematodes. Complaints from several sources indicate a scattering infestation of garden soils in the state. In addition to the garden beet (*Beta vulgaris*) (fig. 3) specimens of root knot were received on parsnip (*Pastinaca sativa*) and salsify (*Tragopogon porrifolius*).

FIG. 3.—Root knot on roots of garden beet.

Cabbage

Black Leg (*Phoma oleracea* Sacc.)—Reported as causing severe injury to cabbage (*Brassica oleracea*) at Dyke, Greene County. This disease has been known from the truck section of the state near Norfolk, but had not previously come to our attention from other localities.

Clover, Crimson

Sclerotium Wilt (*Sclerotinia trifoliorum* Erikss.).—Specimens of crimson clover (*Trifolium incarnatum*) from Burkeville, Nottoway County, bore the characteristic white mycelium and sclerotia of the causative fungus on the roots and crown. The correspondent stated that the infested field contained a number of "sick" spots, three feet or more in diameter, in which all plants had been destroyed.

Cotton

Anthracnose (*Glomerella gossypii* (South.) Edg.).—Affected bolls of cotton (*Gossypium*) were received from Lawrenceville, Brunswick County, with a reported damage of thirty percent in one field of long staple cotton.

Cowpeas

Wilt (*Fusarium vasinfectum* Atk.).—This disease seems to be increasing in the eastern part of the state. Affected plants of cowpea (*Vigna sinensis*) were received from Isle of Wight, Louisa, and Nottoway Counties.

Fig. 4—A cluster of grapes affected with Pestallozia rot.

Grape

Pestallozia Rot (*Pestallozia uvicola* Speg.).—This rot of the grape (*Vitus spp.*) which has been reported from scattered localities in the United States[1,2] and is common in Europe, appeared in a vineyard at Blacksburg in 1915. An inspection in August showed a vigorous development of the rot on a row of a European variety of grapes, the parent stock having been obtained from Switzerland some years previously. Concord grapes in the next row showed no signs of the disease, nor was it found on any but the one variety. Practically all clusters of the susceptible variety showed one or more affected berries and on many all berries were destroyed or showed infection. (fig. 4). The fruit was beginning to ripen at this time and the disease eventually developed to such an extent that no marketable grapes were harvested and destruction was practically complete.

The first sign of the rot is found in sunken, circular spots, 5 mm. or more in diameter, one or more to a berry, and commonly nearest the stem end. Fruit in all stages of development is apparently subject to attack. The spots at first have a bluish-white blush with sometimes a slight purple

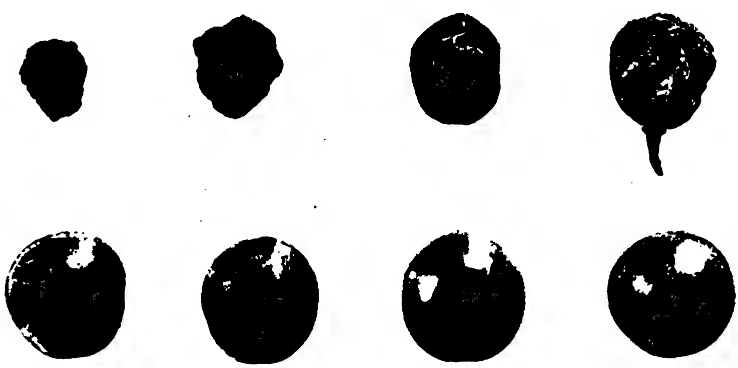


Fig. 5—Stages in the development of the Pestallozia rot of grapes.

cast. They commonly coalesce and form a sunken band around the berry about midway between the equator and the attachment. In late stages the spots become more sunken, darker in color, the berry shrivels and eventually becomes a hard mummy (fig. 5). The rot is essentially a dry-rot

[1]Wolf, F. A.—Ann. Rept., Nebraska Exp. Sta. 21: 69-72. 1908.
[2]Arthur, J. C.—Ann. Rept., Indiana Exp. Sta. 28: 30. 1916.

in character. Pedicels of affected fruits are almost invariably shriveled and probably furnish the entrance point for the inoculum. No mycelium or spores appeared on the surface, but the interior cavities of the berries were found to be filled with a mycelial mat which developed *Pestallozia* in pure culture on media and the same fungus was obtained from pedicels. No leaf-spot recognizable as due to this fungus was observed.

Spraying tests on the control of the disease were instituted during the next season but no rot developed on either unsprayed or sprayed vines.

Peanuts

Wilt (*Fusarium sp.?*).—A wilt disease of the peanut (*Arachis hypogaea*) was brought to our attention in 1916 from Windsor, Isle of Wight County. The disease appeared to be restricted to a half-acre patch in a field of twelve acres and 90 percent of the plants in the infested area had succumbed. The disease had been noticed within the same area during the preceding years. Isolations from diseased plants yielded cultures of a *Fusarium* but inoculation trials were not undertaken. It seems probable that the trouble may be due to a strain of *F. vasinfectum* Atk. which is found on cotton, cowpea and watermelon in this region. Wolf[8] has reported a red rot of the pods of peanut from Alabama caused by the supposed ascigerous stage of this fungus.

Tomato

Fusarium Wilt (*Fusarium lycopersici* Sacc.).—Although not previously reported, this disease appears to be rather widely distributed throughout the state and threatens to become a serious limiting factor in the culture of the tomato (*Lycopersicum esculentum*). In one field under observation this disease had killed over 80 percent of the plants in a roughly circular area about 50 feet in diameter by the middle of the season. Yellowing of branches commencing at the tips followed by yellowing and wilting of the entire plant, are characteristic signs. Successive planting of a field in tomatoes may readily lead to such a general infestation of the soil that culture of that crop is no longer possible. Specimens have been received from Roanoke, Halifax, Henrico, Nottoway, New Kent, Dinwiddie, and Botetourt Counties.

[8]Wolf, F. A.—Alabama Exp. Sta. Bul. 180: 139. 1914.

ANOMALOUS SEED IN ZEA MAYS

By T. K. Wolfe

In the American Naturalist of May 1916, the author published a brief article entitled Fasciation in Maize Kernels, reporting the occurrence of two fasciated kernels of maize and giving a description of their progeny. These seed were from a first-year hybrid ear of a cross between Improved Leaming, as the seed parent, and Boone County Special as the pollen parent. As reported in this article, no fasciated kernels were found in the progeny of the F_1 generation. The progeny of the F_2 generation have now been obtained and the results are presented in tables which follow.

Review of Literature

It seems from the literature reviewed that there have been numerous occurrences of abnormalities in the seed of maize and of the sorghum groups. Among these abnormalities are included inverted seed, connate seed, and two and three seeded spikelets. The phenomenon of connate seed appears to be of less common occurrence than some of the other abnormalities.

The occurrence of two connate kernels in a proterogynous variety of maize is reported by Collins (2) and a discussion of these kernels is presented by Kempton. (4) The latter also reports that a large number of the seeds produced from two-flowered spikelets in the Hopi variety of maize were of the connate type, as were several from a Hopi x Mexican x Chinese hybrid.

The kernels found by the writer and those described by Kempton were united back to back, giving an appearance of one grain with two embryos.

Weatherwax (9) has found two-seeded pods in pod corn. Montgomery (5) found that twinned kernels are especially common in the tassels of pod corn. Sturtevant (8) noted the occurrence of twin kernels in a podded flint corn. Kempton (4) discovered inverted seed in the variety of Hopi maize, in pod corn and in a complex hybrid between varieties of corn from China, Salvador, and Mexico. The latter investigator also found twin kernels in the tassels of pod corn and one spikelet having three well developed seeds. Cron (3) found several triple-seeded spikelets and a large number of twin-seeded spikelets in two panicles of the F_2 progeny of a dwarf milo-feterita hybrid. He was unable to discover any mention of twin-seeded spikelets in pure milo or feterita, but found that twin- and

triple-seeded spikelets occur in some of the other sorghums. Ball (1) found mention of a two-seeded black millet. This author writing about the sorghum of India says: "One or two very large varieties are two seeded; that is, they have two fertile flowers and produce two seeds in each spikelet, instead of one, as is normal for the sorghum."

In the case of maize, it seems that practically all abnormal seed found have been either in pod corn, in some primitive variety, or among hybrids. We might conclude from this that probably these abnormalities arise in the primitive types and varieties because of the lack of specialization of the function of different parts. On the other hand, in the case of hybrids,

FIG. 1—A connate kernel produced by Shenandoah County White, and two-seeded spikelets from a tassel of pod corn.

the tendency to multiple or abnormal production may be due to hybridization. As stated before, the connate kernels found by the writer were produced by a first-year hybrid between Improved Leaming and Boone County Special. In this instance at least, we would not be likely to think of the lack of specialization of the function of different parts, since these varieties are highly bred and selected and are standard varieties in the corn growing sections of the United States. However, Montgomery (6) found an ear of Boone County White corn, practically every kernel of which had three well developed stamens.

Explanation of Abnormal Seed in Maize

The explanation of the occurrence of such seed has been given by Kempton (4) and Weatherwax (9). Various investigators have noted that the staminate and pistillate spikelets are both two-flowered. Both flowers of the staminate are functional, normally functioning as a male, but Weatherwax has found a rudimentary pistil in every staminate flower, which he has so far examined. He has noted in the pistillate spikelet the lower flower is normally aborted and the upper functional with the exception of the variety of sweet corn known as Country Gentleman, in which both flowers are fertile. Stewart (7) has found the same occurrence in this variety. Weatherwax found in the case of the two-seeded pods of corn discovered during his investigations that both flowers of the spikelet had developed. Kempton (4) in his work with Hopi maize found that some of the kernels were apparently inverted; that is, the embryo was on the side of the kernel toward the base of the ear instead of on the side toward the tip. He found the same thing in the case of pod corn and, on dissection, it was shown that the inverted kernel always came from the lower flower. In those spikelets in which both flowers had developed, in nearly every case, the inverted seed came from the lower flower. In the spikelets where the inverted seed were alone, the lower flower was fertile and the upper one aborted. In regard to connate seed, Kempton says: "The union of the seeds which develop from the two-flowered spikelets appear to take place very early, since it is to be observed that the two styles or silks are usually united. There have been no cases observed of the two maize seeds growing together except where both have been produced by one spikelet. In pod corn the seeds produced in the two-flowered spikelets are never united, owing perhaps to the larger and earlier development of the bracts which surround each seed."

The two connate seed found by the writer were apparently enclosed in one pericarp, but they were not examined as to this point or as to their development on the spikelets. However, from the evidence of previous investigators it would seem that both of these kernels were produced by the simultaneous development of both flowers of the spikelet. Also, half of each connate kernel with the embryo toward the base of the ear was produced by the lower flower of the spikelet, and the other half by the upper flower of the spikelet.

FIG. 2—(Left to right.) Upper row, a normal kernel, a connate kernel showing development on a single pedicel, two separate kernels each borne on a separate pedicel. Lower row, two kernels from a single spikelet, and two connate kernels.

F_2 GENERATION FROM CONNATE KERNELS

The pure and hybrid seed produced by each connate kernel in the F_1 generation were planted in alternate rows and allowed to open pollinate. In the F_2 generation there appeared on ears, produced by both the hybrid and pure seed, kernels with the embryo placed on the side toward the base of the ear, some with the embryo on the left side and others with the embryo on the right side. However, on a majority of the kernels the embryo occurred on the side toward the tip of the ear. Also, connate seed and two-seeded spikelets occurred. A certain number of ears produced in the F_2 generation were selected and shelled and the number of different kinds of kernels noted.

In Table I is presented data showing the number of kernels of different kinds produced in the F_2 generation by different ears. Also, the ratio of the kernels with the embryo normally placed to kernels with the embryo placed otherwise.

TABLE I.—*Number of Kernels with the Embryo on the Side Toward the Tip of the Ear, Toward the Base of the Ear, on the Left or Right Side, and the Number of Connate Seed and Two-Seeded Spikelets Produced in the F_2 Generation by Pure and Hybrid Seed from Connate Kernels; Also the Ratio of Kernels with Embryo on Tip Side to Kernels with Embryo Placed Otherwise*

Kernel No. and Kind of Seed Planted	Ear No.	No. of Kernels with Embryo on: Tip Side	Base Side	Left Side	Right Side	Number of Connate Seed	Two-Seeded Spikelets	Ratio of Kernels with Embryo on Tip Side to Other Kernels
	1	524	16	59	48	4	......	4.13:1
	2	584	3	6	3	......	......	48.67:1
	3	356	37	75	60	19	6	1.81:1
	4	662	5	24	27	4	1	10.85:1
	5	144	10	35	43	2	12	1.41:1
I	6	468	4	9	7	......	......	23.40:1
Pure	7	512	11	18	11	2	1	11.91:1
	8	691	2	3	1	......	......	115.17:1
	9	372	4	17	16	1	5	8.65:1
	10	589	......	3	5	......	......	73.63:1
	11	680	......	2	2	......	......	170.00:1
						Ratio for group		8:96:1
	12	412	1	7	3	......	......	37.45:1
	13	607	4	6	4	......	......	43.36:1
	14	503	1	9	14	1	......	20.12:1
	15	478	2	3	5	......	......	47.80:1
	16	792	12	16	14	......	......	18.86:1
	17	542	......	1	......	......	......	542.00:1
I	18	457	......	1	......	......	......	457.00:1
Hybrid	19	559	1	6	3	......	......	55.90:1
	20	358	......	2	1	......	......	119.33:1
	21	579	4	4	4	......	......	48.25:1
	22	513	......	2	2	......	......	128.25:1
	23	744	2	......	3	......	......	148.80:1
	24	626	12	......	......	......	......	52.17:1
						Ratio for group		47.80:1

TABLE I.—*Continued*

KERNEL NO. AND KIND OF SEED PLANTED	EAR NO.	NO. OF KERNELS WITH EMBRYO ON				NUMBER OF CONNATE SEED	TWO-SEEDED SPIKELETS	RATIO OF KERNELS WITH EMBRYO ON TIP SIDE TO OTHER KERNELS
		TIP SIDE	BASE SIDE	LEFT SIDE	RIGHT SIDE			
II Pure	25	162	26	22	84	3	3	1.17:1
	26	599	1	1	1	——	——	199.67:1
	27	348	45	26	14	4	——	3.91:1
	28	278	——	5	2	——	——	39.71:1
	29	572	4	13	9	1	——	21.19:1
	30	345	——	5	3	——	——	43.13:1
	31	411	2	3	4	——	——	45.67:1
	32	487	3	1	3	——	——	69.57:1
	33	315	2	——	1	1	——	78.75:1
	34	470	7	18	11	——	——	13.06:1
	35	216	2	6	6	——	——	15.43:1
	36	332	——	——	——	——	——	——:—
	37	550	1	4	2	——	——	78.57:1
	38	198	6	5	16	——	——	7.33:1
						Ratio for group		14.05:1
II Hybrid	39	300	46	16	32	3	16	2.65:1
	40	437	1	9	5	1	——	27.31:1
	41	355	2	2	1	——	2	50.71:1
	42	263	5	10	11	1	——	9.74:1
	43	336	9	19	14	1	——	7.81:1
	44	560	4	4	5	1	——	40.00:1
	45	386	——	1	——	——	——	386.00:1
	46	717	——	1	——	——	——	717.00:1
	47	751	——	——	3	——	——	250.33:1
	48	468	——	——	——	——	——	——:—
						Ratio for group		20.32:1
						Ratio for four groups		16.45:1

In the foregoing table it will be seen that there is a great variation in the ratio of different kinds of kernels on different ears. However, it seems that there is a tendency for connate seed to be inherited. The occurrence of kernels with the embryo placed other than in the normal way is unusually frequent.

Further Occurrence of Connate Kernels

The writer found a third connate kernel of maize on an ear which had been pollinated with mixed pollen from Shenandoah County White and Reid's Yellow Dent. The ear was borne by the former variety. This

kernel does not show any yellow coloration, thus being a pure Shenandoah County White kernel. If it were a hybrid, we would expect, due to dominance of yellow over white and to xenia in maize, some yellow color to be visible. The connate kernel in question differs from those previously described (10), in that there is only a partial union of the two kernels. The union has taken place at the crowns and along the lower halves of the kernels. The kernels are more or less three cornered in shape, placed back to back, and have two embryos, but on opposite sides. Two connate kernels were found on different ears of Silver King corn and another connate kernel was secured from an ear of Boone County White corn.

BIBLIOGRAPHY

1. Ball, Carleton, R.—The History and Distribution of Sorghum. U. S. Dept. Agr., Bur. Plant Industry. Bul. **175.** 1910.
2. Collins, G. N.—A Variety of Maize with Silks Maturing before the Tassels. U. S. Dept. Agr., Bur. Plant Industry. Cir. **107.** 1913.
3. Cron, A. B.—Triple-Seeded Spikelets in Sorghum. Jour. Am. Soc. Agron. **8**: 237-238. 1916.
4. Kempton, J. H.—Floral Abnormalities in Maize. U. S. Dept. Agr., Bur. Plant Industry. Bul. **278.** 1913.
5. Montgomery, E. G.—What is an Ear of Corn? Pop. Sci. Mon. **68**: 55-62. 1906.
6. Montgomery, E. G.—Perfect Flowers in Maize. Pop. Sci. Mon. **79**: 346-349. 1911.
7. Stewart, A.—The Pistillate Spikelet in Zea Mays. Science N. S. **42**: 694. 1915.
8. Sturtevant, E. L.—Notes on Maize. Bul. Torrey Bot. Club. **21**: 319-343. 1894.
9. Weatherwax, Paul—Morphology of the Flowers of Zea Mays. Bul. Torrey Bot. Club. **43**: 127-144. 1916.
10. Wolfe, T. K.—Fasciation in Maize Kernels. Amer. Nat. **50**: 306-309. 1916.

VALUES OF COMMERCIAL FEEDING STUFFS BASED ON THE NET ENERGY

By C. W. Holdaway

The table of comparative values of feeding stuffs given here has compiled for the use of feeders of cows and beef animals. It enable feeder to transform market quotations of feeding stuffs into compar feeding values on a money basis, to choose the cheapest feeds from a ber of quotations, and to determine when a farm crop can be sold an placed with a cheaper feed.

The basis upon which this table is computed is the net energy valu the different feeding stuffs.* Heretofore feeding values have been b on the percentage of digestible nutrients, but recently it has been sh that the net energy of a feed is a better index of its ultimate produ value to the animal. A part of the digestible nutrients of a ration is in the work of ingestion and assimilation and as the amount so used v greatly with the different feeds it is evident that the final value of feed for growth, flesh formation or milk production is not represente the amount of digestible nutrients. The value has been determined many feeds and is called the net energy. It is the number of heat left after deducting the losses mentioned above.

Although the net heat value of the protein of the feed is include the net energy value, yet it is necessary to know the true protein con of the different feeds to be able to classify them intelligently. Pr serves for body repair and cannot be replaced by any other nutrient a certain amount must be supplied in the rations. The digestible protein is therefore given in the first column of the table.

The first feed tabulated is dent corn, and the values given are in lars and cents per bushel from $0.60 to $2.10, and per ton, for the c sponding values. The values of the different feeds in each column comparable with each other since they are directly in proportion to net energy of each feed. In the first column, if corn is worth 60 c per bushel or $21.42 per ton, any feed in the same column is worth amount specified. If corn meal is quoted at $60 per ton and corn-and meal at $50, then the latter is the cheaper. If the farmer has corn, ba buckwheat and rye, some of which he wishes to market, and corn is w $1.20 per bushel, then from the table in column 7, barley is worth $4 per ton or $0.94 per bushel of 48 pounds, buckwheat is worth $29.94 ton or $0.63 per bushel of 48 pounds, and rye is worth $46.96 per to $0.84 per bushel of 56 pounds. The grains that bring the highest p can be sold first and the low priced grains held for farm feeding purp In general, all the feeds are comparable in this way.

---

*The base values for digestible true protein and net energy used in this table were by permission of the author from Armsby, H. P., "The Nutrition of Farm Animals," pp. 71

68.6	*Packing House.* *Dried blood*	17.07	19.91	22.76	25.60	28.45	31.29	34.13	36.98	39.82	42.67	45.51	48.35	51.20

	Packing House.													
68.6	Dried blood	17.07	19.91	22.76	25.60	28.45	31.29	34.13	36.98	39.82	42.67	45.51	48.35	51.20
	Hay and Fodder.													
3.5	Brome grass, smooth	10.23	11.94	13.64	15.34	17.05	18.75	20.46	22.16	23.87	25.57	27.28	28.98	30.69
2.3	Corn fodder, with ears	11.01	12.84	14.68	16.51	18.35	20.18	22.02	23.85	25.69	27.52	29.36	31.19	33.03
1.6	Corn stover, medium dry	7.92	9.24	10.56	11.88	13.20	14.52	15.84	17.16	18.48	19.80	21.12	22.44	23.76
1.8	Kaffir fodder	8.59	10.02	11.45	12.88	14.31	15.74	17.18	18.61	20.03	21.47	22.90	24.33	25.76
1.0	Kaffir stover	6.93	8.08	9.24	10.39	11.55	12.70	13.86	15.01	16.17	17.32	18.48	19.63	20.79
3.9	Millet, Hungarian	11.76	13.72	15.68	17.64	19.60	21 56	23.53	25.49	27.45	29.41	31.37	33.33	35.29
3.6	Timothy and clover, mixed	10.23	11.94	13.64	15.35	17.05	18.76	20.47	22.17	23.88	25.58	27.29	29.00	30.70
3.9	Oat hay	8.08	9.43	10.77	12.12	13.47	14.81	16.16	17.51	18.86	20.20	21.55	22.90	24.24
3.3	Orchard grass	11.25	13.13	15.00	16.88	18.75	20.63	22.51	24.38	26.26	28.13	30.01	31.89	33.76
2.9	Prairie hay	10.13	11.82	13.51	15.19	16.88	18 57	20.26	21.95	23.63	25.32	27.01	28.70	30.39
3.9	Red top	12.83	14.97	17.11	19.25	21.39	23.52	25.66	27.80	29.94	32.08	34.22	36.36	38.50

METEOROLOGICAL RECORDS FOR THE YEARS 1915 AND 1916

By H. L. PRICE, *Observer*

Reading of the Standard Air Thermometer, 1915

	January			February			March			April			May			June		
DATE	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	7	35	21	44	47	45	24	38	31	26	48	36	46	64	58	56	56	52
2	29	36	29	44	46	45	28	43	38	24	45	37	50	73	65	56	60	57
3	9	36	28	34	34	34	32	43	34	30	33	32	56	74	71	54	59	55
4	26	39	25	26	35	30	21	42	35	28	47	36	56	70	56	53	63	55
5	15	41	37	29	33	34	28	29	30	34	56	46	50	61	54	55	67	58
6	34	41	39	25	48	35	29	41	32	42	68	46	48	72	60	57	74	65
7	39	47	32	32	36	30	31	34	30	46	70	49	60	63	60	63	80	69
8	26	38	31	21	25	22	30	33	29	35	69	53	57	74	59	63	70	62
9	29	40	34	21	32	25	22	36	32	42	76	61	57	68	55	58	71	60
10	24	45	31	14	43	28	31	44	40	49	76	67	46	70	57	55	77	60
11	28	31	29	20	51	36	32	41	36	50	58	49	52	65	58	59	84	71
12	33	34	32	33	54	33	29	40	33	46	58	43	50	61	58	65	84	64
13	31	33	32	32	61	52	16	49	32	36	54	39	61	74	65	67	86	72
14	28	45	39	42	56	53	25	52	32	32	59	43	58	74	61	68	80	70
15	40	47	32	50	51	44	25	53	46	32	61	46	57	74	67	66	63	64
16	24	51	45	35	43	33	40	45	37	31	62	51	56	80	63	63	77	66
17	40	50	47	23	43	35	25	31	26	47	61	51	60	71	50	62	79	78
18	53	59	58	19	45	31	20	42	30	45	67	59	47	69	60	67	81	69
19	32	32	28	21	44	27	31	41	37	46	78	59	51	53	52	70	78	77
20	25	31	25	18	51	30	31	38	32	48	78	63	51	63	56	63	80	71
21	19	22	20	20	58	45	31	36	31	48	69	60	62	80	69	69	73	70
22	21	30	31	32	66	54	27	34	29	49	60	51	61	65	64	70	79	69
23	41	47	34	49	58	49	30	40	33	55	60	55	63	81	62	60	69	59
24	31	25	27	49	49	38	33	39	31	50	77	62	62	78	62	54	70	59
25	29	34	31	34	34	31	24	56	51	55	82	62	59	73	64	54	80	64
26	28	30	30	30	38	33	43	43	32	54	86	65	61	69	69	59	80	66
27	28	38	33	26	40	32	28	40	41	52	87	71	53	59	55	63	83	69
28	32	28	24	24	46	34	23	48	32	57	82	61	59	57	57	65	80	68
29	18	38	30	......	......	......	37	49	40	55	79	65	58	78	61	63	72	66
30	29	34	30	......	......	......	25	39	30	56	71	55	58	67	55	68	74	67
31	26	29	33	......	......	......	27	45	37	......	......	......	49	57	54	......	......	......
Avges	28.2	37.6	32.1	30.2	45.2	36.3	28.3	41.4	34.1	43.3	65.9	52.4	55.3	68.9	59.9	61.5	74.3	65.0

Reading of the Standard Air Thermometer, 1915

Date	July 7 A. M.	July 2 P. M.	July 9 P. M.	August 7 A. M.	August 2 P. M.	August 9 P. M.	September 7 A. M.	September 2 P. M.	September 9 P. M.	October 7 A. M.	October 2 P. M.	October 9 P. M.	November 7 A. M.	November 2 P. M.	November 9 P. M.	December 7 A. M.	December 2 P. M.	December 9 P. M.
1	66	76	63	68	90	71	59	70	58	55	65	64	42	71	54	23	34	30
2	65	75	64	67	73	74	47	70	60	57	67	53	57	62	49	33	37	33
3	61	70	64	72	73	70	57	66	64	46	74	58	38	54	39	27	35	31
4	65	77	69	68	83	71	64	66	65	50	77	65	27	64	51	25	40	26
5	62	71	63	66	80	67	69	72	69	62	62	58	55	64	38	24	36	30
6	60	73	61	60	71	63	61	78	67	52	53	50	30	62	46	25	36	25
7	62	82	69	55	83	67	59	80	68	50	57	51	41	71	50	16	45	26
8	64	78	70	61	85	67	57	84	71	45	55	42	42	71	57	32	46	40
9	63	75	64	65	79	69	61	84	70	36	42	40	61	70	45	32	31	30
10	61	70	65	64	80	68	67	84	70	30	56	38	30	58	38	23	34	22
11	66	79	73	67	75	69	64	88	69	32	63	41	32	72	49	26	29	22
12	72	86	75	67	81	70	63	87	69	30	71	51	45	63	51	23	34	29
13	70	83	70	66	81	70	65	78	68	46	69	61	36	52	42	32	31	27
14	71	86	69	63	84	72	64	87	68	60	65	60	39	43	44	25	26	21
15	64	90	70	69	82	71	64	84	66	55	79	60	42	36	31	17	32	29
16	70	76	73	64	86	69	65	83	68	51	78	74	26	41	27	31	33	31
17	73	73	73	67	68	69	61	87	68	63	76	65	32	56	36	30	46	50
18	66	89	75	61	66	63	65	82	69	62	74	63	30	44	41	44	33	32
19	69	85	73	60	74	65	66	79	65	58	68	60	44	41	36	29	41	28
20	70	71	66	62	66	65	61	77	66	60	68	60	34	49	37	26	29	26
21	63	74	61	68	81	69	64	67	52	59	74	54	44	49	39	23	35	36
22	56	73	63	65	76	64	49	61	43	47	67	57	28	39	23	25	44	30
23	50	77	60	57	80	63	36	65	48	45	66	50	31	48	30	23	52	44
24	57	78	63	56	80	65	40	71	51	50	66	48	37	48	32	38	50	41
25	58	84	70	67	76	64	43	75	56	38	70	51	26	56	35	49	52	30
26	64	84	71	53	78	64	48	75	65	41	74	60	41	55	54	26	33	23
27	67	85	71	62	60	58	69	69	54	43	66	45	41	50	33	19	50	34
28	64	88	72	58	63	61	52	66	60	34	67	47	25	52	44	30	39	40
29	67	86	71	61	76	66	65	55	54	40	69	58	36	38	27	40	46	38
30	69	91	70	62	71	62	53	54	52	49	61	45	23	26	24	35	46	36
31	67	91	77	57	67	60	—	—	—	30	66	42	—	—	—	36	44	37
Avges	64.5	79.8	68.3	63.1	76.4	66.6	58.6	74.8	62.4	47.6	66.5	53.9	37.1	53.5	40.6	28.6	38.7	31.5

Reading of the Standard Air Thermometer, 1916

Date	January			February			March			April			May			June		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	40	58	49	49	42	37	14	36	33	37	71	56	50	77	63	60	75	60
2	57	61	51	32	31	27	33	51	38	46	64	55	55	78	65	51	81	69
3	34	45	31	16	22	20	34	28	20	41	41	39	54	76	66	63	75	60
4	24	50	33	17	32	21	13	25	27	39	58	51	57	72	58	58	72	60
5	33	59	52	19	48	35	38	48	36	40	58	43	52	70	63	55	72	63
6	40	58	41	28	48	48	33	36	48	41	54	44	59	75	56	59	68	63
7	31	28	27	36	38	26	45	56	45	31	40	32	58	74	62	61	64	56
8	24	31	22	18	40	35	30	36	20	31	36	33	57	83	65	58	65	56
9	20	27	24	38	45	36	17	34	31	30	32	32	57	73	61	52	78	56
10	30	45	50	31	49	34	35	46	29	27	46	34	43	78	62	57	72	57
11	50	56	53	30	58	41	21	36	25	33	58	48	64	75	64	57	73	63
12	46	57	51	38	63	49	21	50	39	57	68	56	61	77	61	61	75	60
13	51	45	29	43	26	18	38	62	53	56	80	64	59	83	63	59	77	55
14	20	25	18	9	26	19	43	66	50	64	64	50	61	77	65	57	79	68
15	17	28	27	12	38	31	33	28	19	42	63	50	63	80	65	62	64	60
16	31	37	29	24	47	34	12	27	24	40	68	60	65	71	58	63	67	63
17	11	11	10	42	60	43	23	36	28	55	62	51	48	60	54	58	73	60
18	7	22	18	41	51	30	25	47	38	46	61	52	52	65	54	59	75	63
19	12	34	31	11	26	30	31	43	33	41	74	57	47	70	53	64	76	67
20	30	51	33	30	57	41	23	47	42	50	82	66	50	75	60	63	73	66
21	33	58	56	37	48	31	47	60	52	55	72	55	60	74	64	63	83	70
22	59	53	50	24	58	43	51	70	43	44	50	46	56	52	53	60	77	62
23	30	51	31	41	49	48	28	51	35	45	55	47	57	64	60	60	81	69
24	22	48	36	42	38	36	37	68	57	46	60	48	61	81	65	66	77	68
25	40	59	54	31	33	32	44	77	61	43	49	45	58	80	71	65	75	66
26	52	59	56	26	29	27	58	64	59	41	44	38	62	83	67	63	80	71
27	54	61	52	18	26	23	51	56	46	39	48	42	62	85	66	62	85	72
28	52	64	53	17	30	27	40	45	39	40	56	46	65	89	65	68	85	73
29	48	38	37	26	31	26	37	41	41	37	60	50	62	64	65	67	86	72
30	36	54	48	......	......	......	38	58	53	38	70	53	60	68	58	67	85	67
31	53	62	58	......	......	......	36	67	47	......	......	......	57	68	55	......	......	......
Avges	35.0	46.1	39.0	28.5	41.0	32.6	33.2	48.2	39.0	42.5	58.1	48.1	57.1	74.1	61.5	60.6	75.6	63.8

Reading of the Standard Air Thermometer, 1916

Date	July			August			September			October			November			December		
	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.	7 A. M.	2 P. M.	9 P. M.
1	66	78	69	68	76	65	54	84	69	34	61	41	40	59	40	33	45	34
2	70	80	69	62	63	62	65	75	64	31	64	42	28	66	50	40	52	32
3	72	77	66	67	79	69	61	72	58	35	62	47	32	62	36	24	55	40
4	63	78	62	66	68	77	56	78	61	52	66	62	38	68	50	30	54	51
5	62	78	66	67	85	75	55	78	68	58	69	56	56	70	45	46	66	55
6	63	72	67	72	85	73	61	85	69	54	78	59	30	57	40	38	48	34
7	•60	85	71	71	84	72	61	87	68	50	84	59	42	51	39	22	58	38
8	64	80	67	70	84	73	61	81	68	50	84	62	32	60	47	30	64	56
9	66	68	63	69	71	71	62	79	65	59	75	62	38	70	58	42	36	29
10	69	74	68	68	84	73	61	74	59	56	60	43	48	61	40	20	44	26
11	70	82	72	71	85	69	55	70	55	30	62	42	30	62	42	35	46	34
12	73	85	72	72	83	72	58	70	59	30	68	45	51	53	52	30	28	25
13	73	86	70	71	73	63	61	74	66	34	60	59	51	66	58	18	34	16
14	71	79	70	73	74	64	68	82	70	40	65	43	54	44	36	8	26	26
15	70	70	69	65	69	70	64	69	57	34	63	57	26	28	21	27	26	19
16	66	69	70	69	69	67	44	64	46	59	65	61	18	35	26	7	26	21
17	68	84	72	65	83	72	39	71	54	62	66	48	18	52	35	30	41	31
18	71	80	69	65	83	68	45	73	60	46	44	46	35	42	30	27	21	22
19	68	81	71	61	82	68	44	63	43	53	72	64	27	52	36	11	25	11
20	69	83	72	59	83	66	34	68	47	62	69	48	46	60	38	4	35	36
21	66	83	71	60	84	74	36	75	59	39	52	42	30	57	38	35	44	40
22	69	82	70	68	78	70	48	75	56	34	56	38	30	53	49	38	30	26
23	67	84	73	76	80	68	50	71	53	29	62	40	54	59	47	19	40	31
24	70	75	69	62	74	59	46	67	55	28	67	44	42	42	30	30	40	34
25	67	79	72	54	80	62	42	69	48	32	69	52	23	36	29	38	45	27
26	69	87	68	54	83	64	38	77	54	43	56	38	23	45	30	30	42	37
27	65	67	69	58	84	69	41	79	59	26	61	39	18	53	29	38	54	44
28	67	85	70	62	75	66	51	80	67	29	64	41	30	52	45	51	44	37
29	65	77	65	58	62	60	54	58	49	32	67	53	46	56	50	28	39	32
30	64	84	71	60	78	60	40	60	41	52	61	48	48	49	45	23	38	30
31	64	84	71	52	80	61	......	......	......	50	66	52	......	......	......	17	37	22
Avges	69.4	79.2	68.1	65.0	78.1	67.8	51.8	73.6	58.2	42.6	65.1	49.4	36.1	54.0	40.3	28.0	41.3	32.1

Table Showing Meteorological Data, January 1, 1915, to December 31, 1915

	Mean Temp. for Mo.	Mean Max. Temp. for Mo.	Mean Min. Temp. for Mo.	Average Daily Range	Highest Temp.	Lowest Temp.	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Cloudy Days	Number of Cloudy Days
January	32.6	40.8	24.4	16.0	60	6	54	4.22	3.8	W	11	1	19
February	37.4	48.1	26.8	21.7	66	13	53	2.97	......	W	12	7	9
March	34.8	43.7	25.9	18.0	60	16	44	1.91	7.0	W	11	11	9
April	53.5	68.8	38.2	30.6	89	21	68	1.86	1.0	W	13	13	4
May	61.1	72.7	49.6	26.2	85	36	49	3.73	......	W	11	10	10
June	66.0	78.0	54.0	23.3	88	40	48	2.72	......	W	4	9	17
July	70.2	82.8	57.6	24.8	92	45	47	3.49	......	W	9	16	6
August	69.2	79.3	59.2	19.8	92	46	46	5.87	......	W	15	7	9
September	65.7	77.4	54.0	23.3	89	34	45	4.62	......	W	18	6	6
October	57.2	69.1	45.3	23.5	81	26	55	3.62	......	W	17	10	4
November	43.9	56.6	31.2	25.4	73	20	53	1.41	5.0	W	20	7	3
December	33.6	42.0	25.2	16.7	55	12	43	5.45	8.0	W	9	13	9

Table Showing Meteorological Data, January 1, 1916, to December 31, 1916

	Mean Temp. for Mo.	Mean Max. Temp. for Mo.	Mean Min. Temp. for Mo.	Average Daily Range	Highest Temp.	Lowest Temp.	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Cloudy Days	Number of Cloudy Days
January	40.5	50.4	30.6	19.7	65	7	58	3.12	......	W	7	14	10
February	34.7	45.1	24.3	20.8	65	9	56	4.30	1.0	W	13	7	9
March	40.1	52.3	28.0	24.4	77	11	66	2.52	2.0	W	12	12	7
April	49.2	61.1	37.4	23.6	82	27	55	3.28	4.0	W	16	10	4
May	63.1	77.0	49.3	27.6	89	33	56	3.81	......	W	21	4	6
June	65.4	77.7	52.5	25.2	88	42	46	8.07	......	W	16	11	3
July	71.7	82.3	61.6	20.3	88	50	38	7.79	......	W	16	11	1
August	70.7	81.4	60.1	21.3	89	48	41	3.64	......	W	17	12	2
September	58.2	78.9	37.5	28.1	89	30	59	3.97	......	W	15	4	11
October	53.4	67.0	39.9	29.0	85	25	60	2.88	......	W	11	7	13
November	43.5	56.2	30.8	25.3	72	17	55	1.44	0.5	W	17	4	9
December	33.5	44.0	23.1	20.9	68	2	66	2.46	5.0	W	16	4	11

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

1916—1917

BLACKSBURG, VIRGINIA

LYNCHBURG, VA.
BROWN-MORRISON CO., INC., PRINTERS
1918

TABLE OF CONTENTS

LETTER OF TRANSMITTAL

To His Excellency, Governor Westmoreland Davis:

SIR: In accordance with the Federal laws, approved March 2, 1887, and March 20, 1906, I transmit for your consideration the report of the Virginia Agricultural Experiment Station for the fiscal year ending June 30, 1917. It includes a brief statement of the work completed or in progress, and the principal changes which have occurred since the issuance of the last report.

Respectfully submitted,

A. W. DRINKARD, JR., *Director.*

February 1, 1918.

ORGANIZATION

OF THE

VIRGINIA AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

The Executive Committee of the Board of Visitors of the Virginia Polytechnic Institute.

John Thompson Brown, *Chairman*	R. F. D., Evington, Bedford County
J. B. Watkins	Midlothian, Chesterfield County
J. A. Turner	Hollins, Roanoke County
W. C. Shackleford	Proffit, Albemarle County
J. D. Eggleston, *ex officio*	Blacksburg, Montgomery County

STATION STAFF

J. D. Eggleston, A. M.	President
A. W. Drinkard, Jr., Ph. D.	Director
H. L. Price, M. S.	Horticulturist
W. B. Ellett, Ph. D.	Chemist
W. J. Schœne, M. S.	Entomologist
T. B. Hutcheson, M. S.	Agronomist
F. D. Fromme, Ph. D.	Plant Pathologist and Bacteriologist
G. S. Ralston, M. S.	Field Horticulturist
H. H. Hill, M. S.	Associate Chemist
R. E. Hunt, M. S.	Associate Animal Husbandman
C. W. Holdaway, M. S.	Associate Dairy Husbandman
T. J. Murray, M. S.	Associate Bacteriologist
T. K. Wolfe, M. S.	Associate Agronomist
†W. G. Harris, M. S.	Associate Chemist
S. A. Wingard, M. S.	Assistant Plant Pathologist
S. C. Harmon, B. S.	Assistant Agronomist
C. I. Wade	Treasurer
J. B. Fogleman	Executive Clerk

COUNTY EXPERIMENT STATIONS

T. B. Hutcheson, M. S.	Supervisor County Experiment Stations
W. W. Green (Bowling Green)	Supervisor Tobacco Investigations, and Superintendent Bowling Green Station
B. G. Anderson, B. S. (Appomattox)	Superintendent Appomattox Station
R. P. Cocke (Williamsburg)	Superintendent Williamsburg and Lightfoot Stations
*J. M. Trimble, M. S. (Staunton)	Superintendent Staunton Station
J. C. Hart, B. S. (Chatham)	Superintendent Chatham Station
*A. N. Hodgson, M. S. (Martinsville)	Superintendent Martinsville Station
*M. O. Wilson (Charlotte C. H.)	Superintendent Charlotte Station
E. T. Batten, B. S. (Holland)	Superintendent Holland Station

*In coöperation with the State Board of Agriculture. †On leave for Army service.

Bulletins and reports are mailed free to all residents of the State who apply for them.

Annual Report
of the
Virginia Agricultural Experiment Station
1916-1917

By A. W. DRINKARD, JR., *Director*

President J. D. Eggleston,

Virginia Polytechnic Institute.

SIR: I submit herewith the annual report of the Virginia Agricultural Experiment Station for the fiscal year July 1, 1916 to June 30, 1917.

This station is one unit in the national system of agricultural experiment stations, founded for the definite purpose of promoting agricultural science and improving agricultural practice. All progress in farming must be based upon applied knowledge. The function of the experiment station is to promote scientific investigation and experimentation with the view of acquiring and diffusing among the people useful and practical information respecting the principles and applications of agricultural science. Experiment stations have taken a leading part in the advancement of agriculture during the last quarter of a century, and they have discovered many principles and suggested their application to farming problems. Often the solution of a farming problem involves many underlying principles and requires long-continued investigation, and sometimes there is a tendency for farmers to grow impatient when needed information is delayed. But such delays are unavoidable. It is always worth while to turn the searchlight of science on even the most difficult problem, testing it from every known point of view. Although the progress of investigation may be slow, the experiment station keeps ever in view its duty of enlarging the boundaries of agricultural knowledge and the application of new discoveries to farming.

The experiment station idea is no longer a theory. On the contrary, experiments and investigations in agriculture have come to be recognized as a governmental function of all civilized countries and experiment stations everywhere are receiving increased support. It is noteworthy that many states make liberal appropriations to their agricultural experiment stations, striking examples being found in the appropriations for the fiscal year 1914-1915 of the following states: California, $123,869.21; Illinois,

$195,000.00; Indiana, $91,000.00; Iowa, $106,300.00; Minnesota, $207,093.00; New York, $186,159.60; Ohio, $97,550.08; Wisconsin, $96,215.00.

It would not be profitable to speculate upon the possible state of agriculture at the present day without the aid given during the last thirty years by the experiment stations. However, it is clear that our farmers would not be able to perform so well the unprecedented task now resting upon them without the application of the fundamental principles which have been discovered through the agency of the experiment stations. It may prove to be the case that the farmers of America with their splendid systems of farming will be the vital factor in rescuing the world from the tyranny of militarism and of saving to future generations the principles of human liberty cherished alike by all people whose enlightenment is advanced and whose lives are untrammeled.

PUBLICATIONS

During the year three bulletins were issued and sent to farmers in the State.

Bulletin No. 212—Sudan Grass. By T. B. Hutcheson, E. R. Hodgson, and T. K. Wolfe. 15 pages, 3 figures. November, 1916.

Bulletin No. 213—Spraying and Dusting Tomatoes. By F. D. Fromme, and H. E. Thomas. 14 pages, 3 figures. December, 1916.

Bulletin No. 214—Corn Culture. By T. B. Hutcheson, E. R. Hodgson, and T. K. Wolfe. 12 pages, 2 figures. March, 1917.

The annual report for the years 1915 and 1916, issued in June, 1917, contained, in addition to the usual business and departmental reports, seven technical bulletins and seven special articles setting forth the results of various investigations, as follows:

Technical Bulletin No. 12—The Effects of High Protein and High Energy Rations in Feeding Dairy Cows. By W. B. Ellett, and C. W. Holdaway.

Technical Bulletin No. 13—A Ten-Year Study of the Effect of Fertilizers on the Soluble Plant Food in the Soil and on the Crop Yield. By W. B. Ellett, and H. H. Hill.

Technical Bulletin No. 14—Effect of Soil Moisture on Growth and Maturity in Maize. By T. B. Hutcheson, and T. K. Wolfe.

Technical Bulletin No. 15—Part I—The Effect of Different Plant Tissues on the Fixation of Atmospheric Nitrogen. Part II—A Study of the Bacteriology of Fresh and Decomposing Manure. By T. J. Murray.

Technical Bulletin No. 16—Pot Experiments to Determine Primarily the Availability of Phosphoric Acid in Thomas Slag Phosphates in Comparison with other Phosphates. By W. B. Ellett, and A. A. Ingham.

Technical Bulletin No. 17—Part I—Further Observations on the Effect of Pruning, Root Pruning, Ringing and Stripping on the Formation of Fruit Buds on Dwarf Apple Trees. Part II—Studies on Methods of Protecting Ringing Wounds on Apple Trees to Promote their Healing. By A. W. Drinkard, Jr., and A. A. Ingham.

Technical Bulletin No. 18—The Effect of Hybridization on Maturity and Yield in Corn. By T. B. Hutcheson, and T. K. Wolfe.

Availability of Ground Lime-Stone of Different Degrees of Fineness. By T. B. Hutcheson, T. J. Murray, and T. K. Wolfe.

Dusting for Cedar Rust. By F. D. Fromme, and H. E. Thomas.

Dusting for Peach Scab. By H. E. Thomas.

Plant Diseases in Virginia in 1915 and 1916. By F. D. Fromme.

Anomalous Seed in Zea Mays. By T. K. Wolfe.

Values of Commercial Feeding Stuffs Based on the Net Energy. By C. W. Holdaway.

Meteorological Records for the Years 1915 and 1916. By H. L. Price

In addition to the regular publications of the Station, members of the Staff contributed papers to various scientific journals cited below.

Fromme, F. D., and H. E. Thomas—Root-Rot Disease of the Apple in Virginia. Science N. S. **45**: p. 93. 1917.

Fromme, F. D., and H. E. Thomas—Black Root-Rot of the Apple. Journal of Agricultural Research **10**: 163-174. 1917.

Hutcheson, T. B., and K. E. Quantz—The Effect of Greenhouse Temperatures on the Growth of Small Grains. Journal of the American Society of Agronomy **9**: 17-21. 1917.

CHANGES IN THE STAFF

Several changes occurred in the personnel of the Station during this year. Mr. J. T. Grissom, Assistant Chemist, resigned August 1, 1916, to enter commercial work. Mr. R. H. Cook, Superintendent of the Charlotte County Station, resigned December 31, 1916, to enter the service of the government of Brazil, and Mr. A. P. Moore was appointed in his place. Mr. G. C. Starcher, Associate Horticulturist, resigned December 31, 1916, to accept

the position head of the department of horticulture in the Alabama Polytechnic Institute. Mr. K. E. Quantz, Special Assistant in Horticulture, resigned December 31, 1916, to enter the service of the government of Brazil. Dr. M. T. Smulyan, Assistant Entomologist for the Crop Pest Commission, whose experimental work was affiliated with this Station, resigned December 31, 1916, to accept a position with the Bureau of Entomology, U. S. Department of Agriculture. Mr. H. E. Thomas, who was appointed Assistant Plant Pathologist, July 1, 1916, resigned February 28, 1917, to accept a position with the Porto Rico Station. Mr. A. A. Ingham, who was appointed Assistant Horticulturist, July 1, 1916, died suddenly June 13, 1917, and by his death the Station lost a valued employee who had just entered a career which gave promise of great usefulness. Mr. E. R. Hodgson, Associate Agronomist and Supervisor of the County Stations, resigned June 30, 1917, to become Agronomist for the Extension Division of the College. A part of Mr. Hodgson's duties were assigned to Professor T. B. Hutcheson and part to Mr. T. K. Wolfe, who was promoted to Associate Agronomist.

It is inevitable that some changes will occur from time to time in the Staff; but it is unfortunate that so many changes should take place. Every man who left the Station during the year accepted a new position which paid a larger salary than he was receiving here, and in some cases this difference was very considerable. Virginia can ill afford to permit its trained Station workers to be drawn to other States. The services of these trained workers are worth as much to Virginia as to other States, and it is clearly to the interest of the Commonwealth to support the Station with funds adequate to pay the Station employees salaries in keeping with those paid by other institutions. There is no other solution to this problem. Fortunately, there were no changes in the departmental heads during the year and the continuity of the work has not been interrupted.

FINANCES

Table I sets forth concisely the receipts and expenditures of the Station during the fiscal year. The Station received from the Federal Government $15,000 under the Hatch Act, and $15,000 under the Adams Act. The Supplemental Fund is derived from the sale of farm crops, orchard fruits and live stock—by-products of the Hatch and Adams experiments, and the use of the supplemental fund is regulated by the same rules under which the Hatch and Adams funds are expended. All the federal funds are used at the main Station for experiments and researches of a fundamental character bearing upon agriculture.

TABLE I.—*Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1916-1917*

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS					
Appropriations	$15,000.00	$15,000.00		$16,000.01	$ 5,062.50
Balances from previous year			$ 3,343.23	1,111.42	2,535.83
Farm products, etc.			4,232.36	1,964.54	1,435.71
	$15,000.00	$15,000.00	$ 7,575.59	$19,075.97	$ 9,034.04
DISBURSEMENTS					
Salaries	$ 8,965.96	$ 8,894.90	$ 67.50	$ 9,226.24	$ 3,633.32
Labor	2,452.56	2,490.19	547.92	3,938.09	1,741.57
Publications	457.44		969.18		
Postage and stationery	387.55	5.72	44.52	113.98	73.14
Freight and express	138.31	57.26	56.09	24.55	13.75
Heat, light, water and power	138.58		200.00		
Chemicals and laboratory supplies	29.59	433.77	14.50		
Seeds, plants and sundry supplies	452.88	194.71	896.48	558.96	559.29
Fertilizers	498.32	370.23	7.20	972.00	464.24
Feeding stuffs	282.75	1,256.36	440.18	308.79	26.25
Library	173.55		21.00		
Tools, machinery and appliances	476.43	208.06	26.60	141.58	18.50
Furniture and fixtures	94.43	10.50		102.98	49.00
Scientific apparatus and specimens		213.67	2.50	11.20	
Live stock	171.15	450.00	50.00	211.00	
Traveling expenses	234.92	226.68	23.44	1,067.30	154.58
Contingent expenses	40.00			100.00	68.13
Buildings and land	5.58	187.95	158.80	435.03	875.99
Balances			4,049.68	1,864.27	1,356.28
	$15,000.00	$15,000.00	$ 7,575.59	$19,075.97	$ 9,034.04

The State Legislature appropriated $16,000 to be used in experimental work out over the State, specifying that $8,500 of this amount should be used for the special purpose of conducting investigations, experiments and demonstrations with tobacco and crops grown in rotation with tobacco or in connection with tobacco; and that $7,500 of this amount should be used for County Experiment Stations. No part of the State fund can be used for experiments at the main Station at Blacksburg.

The State Board of Agriculture supports the experimental work at the Staunton, Martinsville and Charlotte Court House Stations, for which $6,750 was appropriated. During the fiscal year covered by this report only $5,062.50 was received from this source, which together with the balance brought forward from the previous year, and the amount received from the sale of farm products, was sufficient to handle the experimental work nicely. The Experiment Station supervises the experimental work at these three county stations. This co-operative arrangement has been very pleasant throughout and has been of great value to the agriculture of the State in that it has enabled the Station to enlarge its service to the farmers. The fact that this Station supervises the work has made it possible to co ordinate experimental work in the State, which is a question of importance form the standpoint of economy and efficiency.

Further Appropriations Needed

It is my duty to point out the fact that more money is needed to enable the Station to perform the service for the farming interests of the State both needed and demanded by the farmers. The present Legislature has been requested to increase by $4,000 the appropriation for experimental work at the County Stations, and to make an appropriation of $10,000 under the provisions of chapter 226, Acts of the General Assembly of the State of Virginia, 1906. The act here referred to defines the purposes for which the money shall be used and is modeled after the Federal Hatch Act. The amount of money requested of the Legislature is no more than sufficient to make up the depreciated purchasing power of the income now received by the Station, and when normal economic conditions again return this increased income will permit the Station to expand its activities along lines which greatly need investigation.

PROGRESS AND RESULTS OF EXPERIMENTAL WORK UNDER EACH PROJECT

A brief statement follows showing the progress and results of the experimental work under each project, the projects being grouped according to the departments responsible for them.

Horticultural Department

Effects of Soil Environment on Fruit Bud Formation (Adams Fund).—The object of the investigations now being made under this project is to secure further knowledge regarding the specific role of the leading mineral elements of plant food singly and in combination in the formation of fruit buds. The moisture factor and methods of soil management are taken into consideration also. The experiments are carried on under controlled and field conditions.

The controlled experiments are performed on dwarf Mother apple trees growing in cylinders. The cylinders were made of galvanized iron, 24 inches in diameter without bottoms. The cylinders were set in the ground over 3-inch tile to provide proper drainage. Coarse stones, fine stones and cinders were placed in the bottom of the cylinders to prevent water from rising in the cylinders. Then the cylinders were partly filled with clay, on top of which was placed silt loam, thus simulating the Hagerstown silt loam of this region. The dwarf apple trees were planted in the cylinders in 1911. There are three series of cylinders, according to the moisture content of the soil. The first series is left open and receives the

FIGURE 1—Experiments on fruit bud formation. A general view of Series II. Dwarf mother apple trees in full bloom showing the covers which exclude rainfall from the cylinders. Photo May 6, 1916.

rainfall, but no water besides; rainfall is excluded from the other two series of cylinders by means of covers, and water is supplied the trees artificially. The second series receives enough water to maintain a low percent of moisture in the soil during the growing season. The third series receives enough water to maintain the optimum percent of soil moisture during the growing season. From time to time the moisture content of the soil is determined during the growing season. These three series are crossed by fertilizer plats, on which nitrogen, phosphoric acid, potash and their combinations respectively are applied; certain check plats receive no fertilizer.

TABLE II.—*Showing the Average Number of Blooms on All Trees in Each Plat for the Years 1913, 1914, 1915, 1916, and 1917.*

FERTILIZER TREATMENT	CHECK	NITROGEN	PHOSPHORUS	POTASH	CHECK	N AND P	N AND K	N, P AND K
Series I—Rainfall	873	1037	818	765	660	1222	1057	1182
Series II—Low Moisture	587	749	519	656	556	523	799	684
Series III—High Moisture	630	1128	596	539	566	831	809*	866
Plats	1	2	3	4	5	6	7	8

*One tree missing in 1917.

TABLE III.—*Showing Rates at Which Fertilizers Were Applied in Pounds Per Acre for the Five Years.*

YEAR	NITRATE OF SODA	DRIED BLOOD	16 PERCENT ACID PHOSPHATE	SULPHATE OF POTASH
1913	25	35	125	25
1914	50	75	250	50
1915	75	125	375	50
1916	75	125	375	75
1917	75	125	375	75

It may be seen from the first table that the fertilizer applications so far have not produced very marked differences in the formation of fruit buds; not so much as the differences due to the moisture content of the soil.

The field experiments under the project are being carried out in two orchards, one located at Blacksburg and the other at Crozet, both planted in 1911. The moisture content of the soil in these orchards is regulated in some measure during the growing season by different methods of soil management. Each orchard is divided into three parts, or series. The

FIGURE 2—A view of apple trees in Series I, Blacksburg orchard, showing cover crop of buckwheat in full bloom. Photo July 13, 1916.

first series of trees receives frequent cultivation during the growing season so as to conserve the moisture. At the Blacksburg orchard, provision was made in 1913 for applying water to the trees in Series I, and it is possible to maintain a high percent of moisture in the soil; but at the Crozet orchard the moisture content of the soil can be regulated only by cultivation. The second series of trees receives cultivation in the same manner practiced by commercial fruit growers in the State, and this method of cultivation conserves moisture to a less extent than the method followed in Series I. The third series of trees has been kept in sod since 1913; and the grass on the land removes moisture from the soil rather rapidly during the growing season and less water is available to the fruit trees in this series than to those of either of the other two series.

Each cultural series is crossed by eight plats on which the effects of fertilizers are studied.

Plat 1. Check.
2. Nitrogen from nitrate of soda and dried blood.
3. Phosphorus from 16 percent acid phosphate.
4. Potash from sulphate of potash.
5. Check.
6. Nitrogen and phosphorus.
7. Nitrogen and potash.
8. Nitrogen, phosphorus and potash.

FIGURE 3—A view of Series I peach trees, Blacksburg orchard. The land receives high cultivation, and when necessary the land is irrigated to maintain abundant moisture in the soil during the growing season. Photo June 22, 1915.

TABLE IV.—*Showing Rates at Which Fertilizers Were Applied to Peach Trees in Crozet Orchard in Pounds Per Acre for Five Years*

YEAR	NITRATE OF SODA	DRIED BLOOD	16 PERCENT ACID PHOSPHATE	SULPHATE OF POTASH
1913	25	35	125	25
1914	50	70	250	50
1915	100	150	350	50
1916	100	150	350	50
1917	100	150	350	50

Three varieties of apples and three varieties of peaches are used in each orchard. In the Blacksburg orchard there are 21 apple trees in a plat and 18 peach trees in a plat. In the Crozet orchard there are 35 apple trees

in a plat and 18 to 21 peach trees in a plat. The twig growth and increase in circumference of the trunks are measured each year. Careful records are made on the fruit bud formation, bloom and crop on each individual tree. Marked differences now appear in the growth of the trees in the three cultural series, but the fertilizer treatments within the series do not yet show consistent results. The yield for the Elberta and Early Crawford peach trees is given in the table which follows. The Carman trees which were planted proved to be a mixture of about one-third Carman and two-thirds Hiley, and the yields from these mixed varieties are not given here.

TABLE V.—*Showing Yields of Fruit in Pounds by Plats of Elberta and Early Crawford in the Three Series of the Crozet Orchard for the Years 1915, 1916, and 1917.*

VARIETIES	SERIES	PLAT 1	PLAT 2	PLAT 3	PLAT 4	PLAT 5	PLAT 6	PLAT 7	PLAT 8	TOTAL
Elberta	I	150.0	1,797.0	2,312.0	1,902.5	1,143.0	1,735.0	1,884.0	1,385.5	12,309.0
	II	676.5	1,049.5	512.0	460.0	765.0	845.0	1,254.0	833.0	6,395.0
	III	520.5	711.0	665.5	590.0	300.0	824.5	949.0	682.5	5,248.0
Early Crawford	I	153.0	901.0	681.0	945.0	796.0	849.0	1,111.0	952.0	6,388.0
	II	589.0	615.0	837.0	464.0	484.0	564.0	842.0	604.0	4,999.0
	III	405.0	601.0	362.0	415.0	190.0	491.0	133.0	394.0	2,991.0

The peach trees in the Blacksburg orchard have produced only one crop because of winter injury to the fruit buds. The apple trees have not fruited yet in either orchard.

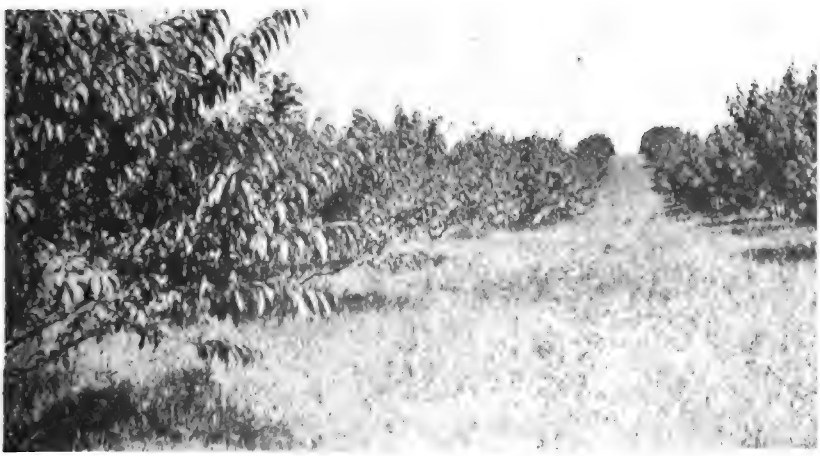


FIGURE 4—A view of Series III (the land is kept in sod) peach trees, Blacksburg orchard. Compare with Figure 3. Photo July 13, 1916.

In the spring of 1915 a four-acre orchard of apple trees was planted at Blacksburg to study the effects on fruit bud formation of pruning at different seasons and in different amounts. This work consists of a line of experiments closely related to the main project.

During the fiscal year covered by this report a paper was issued on "Further Observations on the Effects of Pruning, Root Pruning, Ringing and Stripping on the Formation of Fruit Buds on Dwarf Apple Trees." This is a part of Technical Bulletin No. 17.

Breeding Late Blooming Apples (Adams Fund).—The varieties, Mother, Melon, Ralls and Ingram bloom later than most other varieties and these are used as foundation stock in this project. The standard commercial varieties including York Imperial, Stayman Winesap, Winesap, Yellow Newtown, Rome, Delicious, Jonathan, Ben Davis, Arkansas and others, are crossed on these late blooming kinds with the object of combining commercial qualities with the late blooming character. A number of hybrid seedlings have been secured, but none of these have yet fruited. No additional crosses were made this year on account of the fact that there was very little bloom on any of the varieties used in this experiment, this being the "off year" for apples in this section.

Commercial Value of Dwarf Apple Trees (Hatch Fund).—The object of this experiment is to determine the value of dwarf apple trees for commercial planting. At the time this experiment was started there was considerable agitation in favor of the so-called "half dwarf" apple tree for commercial work. It was claimed that these dwarf trees should come into bearing much earlier than standard trees and that on account of this dwarfish growth habit, pruning, spraying, thinning and harvesting would be less difficult and that it would therefore, be possible to produce a higher class fruit-product on a dwarf than on a standard apple tree.

It was common experience at this time that certain varieties produced very satisfactory crops on dwarf stocks when planted for home use, but little was known of the behavior of our standard commercial varieties when propagated on dwarf stocks.

In 1907, twenty-five trees each of twenty-four standard commercial varieties propagated on Doucin or half dwarf stocks were planted on a rather heavy type of Hagerstown silt loam found on the Station grounds. Although this soil was somewhat run down in fertility and subject to erosion, the location was ideal from the standpoint of air and soil drainage, and its treatment subsequent to planting has been favorable to early bearing. In addition to the twenty-four standard varieties mentioned above, five trees each of about fifty additional varieties of secondary importance for commercial work were planted at the same time.

It is a noteworthy fact that from this planting of numerous varieties on half dwarf stocks only a small number of these varieties come into bearing much earlier than when grown on standard stocks. In fact the Yellow Transparent is the only strikingly early and consistent bearer in the lot. This variety has borne full crops in alternate years since the third year from planting. It is exceedingly prolific and the size and quality of the fruit is superior to that of the same variety on standard stocks in a nearby

FIGURE 5—Yellow Transparent Half Dwarf apple tree, nine years old when photographed, carrying heavy crop of fruit. The background is marked in square feet. Photo July 11, 1916.

orchard under practically the same soil and cultural conditions. Several other varieties have fruited in a very satisfactory way on dwarf stocks, although they were about as slow coming into bearing as when progagated on standard roots. Among the varieties that have borne satisfactory crops after the seventh year, may be mentioned, Jonathan, King David, Lady, Gano, Ben Davis, Black Ben Davis or Reagan, Red Astrachan, Bismark, Virginia Beauty, Wagener and Rome. Other varieties including York Imperial, Lankford, Northern Spy, Winesap and Baldwin have thus far

yielded very little fruit. Delicious and Senator were planted several years after the main planting, but it may be said they are not especially early bearers on dwarf stocks.

Dwarf trees have the advantage of being easily sprayed and pruned and the fruit may be harvested without difficulty. These are undoubtedly advantages which are worth considering in commercial work. On the other hand, however, dwarf apple trees appear to have rather superficial root systems and a strong tendency to sucker at the crown of the tree. This suckering would indicate weakness in tree growth. It is generally conceded that dwarf trees are not long lived. It is obvious also that the acre yield from dwarf trees can never be as large as that from standard. Even where the trees are closely planted, the bearing area of dwarfs as compared with that of standards is distinctly in favor of the latter. On the whole the fruit produced on dwarf trees appears to be of larger size and better color, than that of the same variety on standard stocks.

The indications of this experiment are that the dwarf tree has a distinct place in the home fruit garden where only a small area of land is available for tree planting, and that certain varieties propagated on dwarf stocks will give very satisfactory results in this connection. From the standpoint of using dwarfs for commercial planting, however, the outlook is by no means as promising. In fact so far as these experiments go, the results would tend to discourage the planting of dwarf trees in a commercial orchard. The best dwarfing varieties might be used in this connection as filler trees, but we do not think that the dwarf should be planted for permanent growth.

Control of Fire Blight (Hatch Fund).—An experiment performed at this Station in 1901 and 1902 seemed to indicate that heavy applications of a fertilizer composed of two parts of 16 percent acid phosphate and one part of muriate of potash had a tendency to hold in check the fire blight disease on pear trees. (See Bulletin No. 135.)

In 1910, an experiment was begun for the purpose of testing more fully the influence of mineral fertilizers on fire blight control. The Bartlett and Sheldon varieties of pears on dwarf stocks were used, and 75 trees of each variety were planted. During the first three seasons all of the trees received similar cultivation in spring and summer, followed by a cover crop of crimson clover. The trees made good growth and there was some fire blight present in the orchard every season. The blighted shoots were cut in the usual manner.

In 1913, cultural and fertilizer treatments of the pear trees were differentiated. The land in part of the orchard was left in sod and part of it was cultivated and the orchard was crossed by fertilizer plats.

TABLE VI.—*Showing Fertilizer Treatments Given the Bartlett and Sheldon Pear Trees in the Fire Blight Experiments*

VARIETY	PLAT	TREATMENT
Bartlett	1	Check—received no fertilizer
	2	Potash, from sulphate of potash
	3	Phosphorus, from 16 percent acid phosphate
	4	Nitrogen, from nitrate of soda and dried blood
	5	Nitrogen, phosphorus and potash
Sheldon	6	Check—received no fertilizer
	7	Potash, from sulphate of potash
	8	Phosphorus, from 16 percent acid phosphate
	9	Nitrogen, from nitrate of soda and dried blood
	10	Nitrogen, phosphorus and potash

The fertilizers were applied by hand around the trees at the rates indicated by years in Table VII.

TABLE VII.—*Rates in Pounds Per Acre at Which Fertilizers Were Applied to Plats for Control of Fire Blight for Five Years*

YEAR	NITRATE OF SODA	DRIED BLOOD	16 PERCENT ACID PHOSPHATE	SULPHATE OF POTASH
1913	25	35	125	25
1914	50	70	250	50
1915	75	105	375	75
1916	75	105	375	75
1917	75	105	375	75

In 1914, fire blight was quite prevalent in this section on both apple and pear trees, and in 1915 the epidemic became very severe, perhaps doing more damage than at any former time in this community. It occurred in the so-called "bloom form," "shoot form" and also attacked branches and trunks of both apple and pear trees. The epidemic receded in 1916 and 1917. These seasons afforded a very good opportunity for observing the influence of mineral fertilizer on the development of this disease.

The results of the experiments may be summarized in a few words. The pear trees blighted badly and in about the same degree in all plats irrespective of cultural and fertilizer treatments. There was no appreciable protection against fire blight from applications of acid phosphate and sulphate of potash.

This project has been discontinued.

Variety Studies (Hatch Fund).—From the beginning of its work, the Station has given attention to the question of varieties. At present there are growing on the Station grounds many varieties of apples, peaches, grapes, gooseberries, currants, raspberries and blackberries. The behavior of varieties is observed also in different parts of the State. The object of this work is to secure for the benefit of fruit growers in the State authentic information regarding the value of different varieties. The information secured in these studies has enabled the Station to advise fruit growers regarding the selection of varieties and the advice given has done much towards the building of the commercial fruit growing industry in the State.

Experimental Orchards (State Fund).—Orchards are leased at several points in the commercial fruit growing regions of the State for the purpose of conducting experiments on methods of soil management, including culture and cover crops, and methods of fertilizing orchards. This project has not progressed far enough to give definite conclusions.

Chemical Department

Fixation of Phosphoric Acid in Soils (Adams Fund).—The work was continued as in previous years. Samples of soil were analyzed from the twenty-six plats by the N/5 nitric acid method. These plats, receiving different forms and different amounts of phosphoric acid, have been in corn continuously for ten years, and an effort is being made to correlate the crop yield with the amount of phosphoric acid dissolved by the N/5 nitric acid method. Technical Bulletin No. 13, "A Ten-Year Study of the Effect of Fertilizers on the Soluble Plant Food in the Soil and on the Crop Yield," was issued in June, and it gives the progress of the experiments under this project. This report points out the fact that many types of soil in Virginia are deficient in phosphoric acid, and that different soils have the power of fixing or retaining phosphoric acid in different degrees. The fifth normal nitric acid method failed to show the true availability of phosphoric acid from different sources in comparison with crop yields. A reserve supply of phosphoric acid is built up in soils by annual applications of phosphoric acid, if the amounts applied are in excess of the requirements of the plants growing on the land.

The Effect of Green Manuring on Soils (Adams Fund).—This project is carried on in co-operation with the Agronomy Department. This work as originally outlined, consisted of greenhouse, laboratory, pot and field experiments. The greenhouse and pot experiments have been carried out and the results have been published, but as the work in the field experiments progresses certain points must be checked from time to time by these methods. The laboratory and field work is still in progress. At the present

time the principal work under this project consists of two groups of field experiments.

The first group of experiments has been under way since 1914. Data are available for four years on nitrate accumulation, nitrogen fixation, ammonification of organic nitrogenous substances, total carbon changes and lime requirement under legume and non-legume treatments. Additional work has been done to corroborate a former statement that soil acidity, due to the incorporation of green materials with the soil, is transitory. This point seems to hold good so far as the investigations have gone. However, this point will be checked by lime requirement determinations which are made periodically. In addition to this fact, interesting material has been obtained on the seasonal nitrate changes under such treatments. The nitrogen fixing power of the soil under study has been materially increased under a green manure treatment. The experiments have not yet yielded definite conclusions regarding ammonification changes, as there is more or less fluctuation from time to time. Interesting results obtained along this line of investigation have given rise to an entirely new line of attacking the problems of ammonification and nitrate accumulation, which gives promise of definite conclusions on these very important bacteriological processes. The humus and carbon contents of the soil have been materially increased and the physical condition of the soil greatly improved under green manure treatment.

In addition to the chemical and bacteriological results, crop yields for the entire six years have been obtained which are shown in Tables VIII and IX. The records show material increases in yield of wheat and corn where legumes are used as green manure; but the increase in yield is not striking where non-legumes are used—probably because a poor stand of rye was secured. This is being corrected as far as possible by changing the date of seeding the rye. The tables which follow show the yields of corn and wheat from the two series of plats. It may be stated in this connection that the green manure crop of rye was poor owing to unfavorable seasons.

TABLE VIII.—*Showing Yield of Corn in Bushels Per Acre for Five Years Under Different Methods of Green Manuring*

Plat	Treatment	Years 1912	1913	1914	1915	1916	1917	Five-Year Average
1	Clover turned under	34.46	36.42	37.50	55.80	65.58	38.04	44.63
2	Clover cut for hay	26.46	22.14	31.80	50.26	63.30	32.63	37.77
3	Check	18.93	15.18	27.90	21.43	16.47	15.09	19.17
4	Rye turned under	17.68	12.68	23.80	22.95	22.14	12.38	18.61
5	Rye cut for hay	21.96	17.68	34.50	30.08	30.45	19.28	25.66

TABLE IX.—*Showing Yield of Wheat in Bushels Per Acre from the Plats for the Years 1912, 1914 and 1916, Under Different Methods of Green Manuring*

PLAT	TREATMENT	1912	1914	1916	AVERAGE FOR THE THREE YEARS
1	Soy beans cut for hay	16.00	20.16	22.40	19.52
2	Soy beans turned under	18.66	20.83	29.40	22.96
3	Check	10.30	10.00	24.17	14.82
4	Buckwheat cut for hay	9.30	13.75	16.79	13.28
5	Buckwheat turned under	8.50	15.16	20.50	14.72

The second group of field experiments deals with the effect of turning under green manuring crops at different stages of growth. These experiments have not progressed far enough to give definite conclusions, but there seems to be a gradual diminution of protein in maturing plants. In this group of experiments the soil and the growth and composition of the green manuring plants will be subjected to critical chemical study.

The chemical department has the following co-operative experiments: Protein and Energy requirements for Milk Production, with the Departments of Dairy Husbandry; fertilizer rotation, with the Agronomy Department; ensilage experiments, with the Agronomy Department.

Agronomy Department

A Study of Some Principles Governing Growth and Maturity of Corn (Adams Fund).—This project was undertaken to gain more definite knowledge relative to the time required for the germination of different varieties under constant temperature, the correlation between weight of kernels and time of germination, the relation between time of germination and time of maturity, the length of the growing season as affected by high and low altitudes, the effect of high and low percents of soil moisture upon growth and maturity when water is applied at different stages in the development of the corn plant, the effect of inorganic salts upon maturity and the effect of hybridization upon maturity. Progress was made on this project during the year. Experiments upon the effect of soil moisture on growth and maturity in corn and the relation of the time of germination to the time of maturity are being repeated for the third time in the greenhouse under controlled conditions. The effect of hybridization on maturity and yield, and the effect of climatic conditions on maturity and yield are being studied under field conditions. Two publications were issued during the

year setting forth the results secured from experiments under this project. Technical Bulletin No. 14, "Effect of Soil Moisture on Growth and Maturity in Maize," shows that optimum soil moisture throughout the period of growth promotes both maturity and yield. The early stage of growth of the corn plant is the critical time as regards moisture requirements; and the supplying of abundant moisture at earing time, following periods of deficient moisture, retards maturity and reduces the yield. Technical Bulletin No. 18 "The Effect of Hybridization on Maturity and Yield in Corn," supplies further experimental data on this subject, and shows that there exists marked earliness in the time of maturity of some hybrids in comparison with the parental varieties, and in every case the hybrids matured at a date which was earlier than the average date of maturity for the parental varieties. Along with increased earliness of maturity there was also an increase in yield of the first generation hybrids.

Fertilizer Rotation Experiment (Hatch Fund).—This is a co-operative project between the departments of agronomy and chemistry.

This experiment was started in 1908 for the purpose of determining the best fertilizer treatment for soils similar to those on the Blacksburg experiment grounds. For this purpose fifty-six eighth-acre plats were laid off into four series of fourteen plats each, and a rotation was established of corn, wheat and clover and grass, bringing each series of plats into one of these crops each year, thus giving a crop of corn, a crop of wheat and two crops of hay each year. The fourteen plats in each series were fertilized with different combinations of plant food in the form of manure and commercial fertilizers each year. In 1912, the results from this experiment were so conflicting that it was found necessary to divide each plat into half, leaving one-half unfertilized as a check. Some of the problems involved in this experiment are: (1) The relative importance of nitrogen, phosphorus and potassium alone and in combination in crop production; (2) The relative value of acid phosphate and raw rock phosphate as sources of phosphorus for plants, and (3) the relative value of light applications of farm yard manure made annually and heavy applications made once in four years.

Though the results of these experiments are not yet conclusive, they suggest that in the rotation under test, crop production may be maintained at its present standard by the application of phosphorus in an available form, and that nitrogen and potassium do not give paying returns in this rotation at the prices the crops have brought. When acid phosphate and raw rock phosphate were both applied at the rate of 70 pounds of P_2O_5 per acre, good returns were obtained from the acid phosphate, while raw rock phosphate failed to give increased crops sufficient to pay for the material and its application.

When manure was applied at the rate of four tons annually, larger yields were obtained than when sixteen tons were applied once in four years.

This experiment is being continued.

Cereal Investigations (Hatch Fund).—This work consists chiefly of variety tests, cultural tests, and selection work with corn, wheat, oats, rye and barley. Two strains of wheat and one of winter oats have been segregated which seem to be superior to the best commercial varieties. These are now being tested further at the county stations. An early variety of corn, Wisconsin No. 7, was introduced in 1916. This seems particularly suited for growing at high elevations where seasons are short and for planting in young orchards where tall stalk growth is objectionable. Experiments on corn culture and wheat culture have yielded results which now warrant publications on these two subjects.

Pasture Management (Hatch Fund).—The pasture management work carried on since 1908 in co-operation with the U. S. Department of Agriculture, Office of Forage Investigations, will terminate with the year 1917. Clipping experiments to determine the comparative value of various pasture grasses are being continued, as are the experiments upon the eradication of pasture weeds by chemical sprays.

Forage Investigations (Hatch Fund).—The experiments with annual forage plants are being continued. The results of the work with Sudan grass were published in Bulletin No. 212. The results of experiments with cowpeas and soybeans will be ready to report at the end of the present growing season.

Potato Studies (Hatch Fund).—The potato experiments are being continued as outlined. A report of the potato cultural experiments is now being prepared and will be ready for publication before the 1918 crop is planted. A strain of Green Mountain potatoes has been segregated by the "tuber unit" method which seems to be superior to local varieties in both quality and yield.

Alfalfa Experiments (Hatch Fund).—These experiments so far indicate that alfalfa is an extremely uncertain crop for Blacksburg conditions. They are being continued in the hope of finding some method of making this crop profitable.

Rotation and Fertilizer Experiments (Hatch Fund).—Two-, three-, four- and five-year rotations started in 1912 are being continued. Fertilizer rotations were started in 1916 for the purpose of determining the best time for applying acid phosphate and farm yard manure in a rotation of corn, wheat, and grass two years. An experiment was also started to compare acid phosphate and raw rock phosphate as sources of phosphorus when applied on an equal money value basis to corn, wheat and grass.

Lime Tests (Hatch Fund).—Experiments are being carried on with burnt lime, ground limestone and marl, to determine the most economical source of lime. Pot experiments are being carried on with ground limestone of different degrees of fineness.

Ensilage Experiments (Hatch Fund).—These experiments are in co-operation with the Department of Chemistry to determine the best variety of corn for ensilage, the best stage for cutting ensilage corn, and the value of other forage crops for ensilage purposes. Both total yields and total amounts of protein, fats and carbohydrates are being considered.

The County Experiment Stations (State Funds)

There are eight County Stations, three of which are financed by the State Board of Agriculture, and are located at Staunton, Charlotte, and Martinsville; and five are financed from State appropriations, and are located at Holland, Williamsburg, Bowling Green, Appomattox, and Chatham.

The chief reasons which led to the adoption of the policy of establishing County Experiment Stations were, first, the comparative inaccessibility to many farmers, of the main Station at Blacksburg; and secondly, the great differences in soil types and climatic conditions in the several regions of the State, which make it impossible to do experimental work on all crops at the same place. Annual field days are held at these County Stations when large numbers of farmers assemble to avail themselves of the opportunity to become acquainted with the experiments and hear lectures by experts on different agricultural subjects.

Chatham, Pittsylvania County.—Work at this Station has been in progress since 1904. The work consists largely of fertilizer experiments with bright tobacco, studying the residual effect on the crops that follow in the five-year rotation. The use of lime in connection with the different forms of commercial fertilizer and its effect on the principal crops of this section are studied. A set of plats of one acre each is used as demonstration plats, on which the proper methods of crop rotation, fertilization and cultivation are used. Variety tests of corn and tobacco are conducted each year. A field meeting is usually held in August and these annual meetings are well attended, the farmers of the county having opportunity to see the experimental results in the field. The experiments here have proved it inadvisable to grow leguminous crops in the rotation where fine bright tobacco can be grown; still there is no excuse for the one-crop system which commonly prevails in this section. By laying out a portion of the farm and using a rotation of tobacco, small grain and herds grass, the remainder of the land may be brought to a high state of productivity

by the use of grasses and leguminous crops. This is shown by the heavy yields of hay and grain where this method is followed.

Appomattox, Appomattox County.—The main lines of work consist of fertilizer tests on tobacco and crops grown in rotation with tobacco.

During the season of 1916 some changes were made and additional projects were initiated. One change was in the crop rotation. Previous to this season the crop rotation was in this order: Tobacco, wheat, grass (two years), corn, followed with crimson clover at the last cultivation, cowpeas or soybeans, tobacco. For some cause the tobacco did not seem to grow off well, following peas and beans. Hence this season it seemed wise that another rotation be started. Now it is conducted as follows: Tobacco, wheat, grass (two years), and tobacco again the fifth year. Excellent results were obtained the first season with tobacco following grass. In the previous system of rotation six plats were required, in the latter only four plats, hence in the other two plats the following rotation is being tried: Soybeans, land seeded to rye and crimson clover after beans are harvested; second season this rye and clover is fallowed and corn planted; after the corn is harvested, rye is seeded for a fallow crop for soybeans.

The variety tests include soybeans, cowpeas, potatoes, alfalfa, and tobacco. Tests with soybeans and cowpeas were conducted with the idea

FIGURE 6—Experiments on fertilizers for tobacco on the Bowling Green county station. The plat on the left received a heavy application of complete fertilizer, which produced a splendid growth of tobacco; the plat on the right received no fertilizer whatever and the tobacco plants made very poor growth.

of finding out the best and most prolific varieties for this section. In potato tests, the aim was to find out the best late variety for this section.

Bowling Green, Caroline County.—The U. S. Department of Agriculture, in co-operation with the Experiment Station, undertook certain experiments at this place in 1908, which have been continued to the present time. In conducting these experiments especial attention has been directed to fertilization, cultural methods, combating insects, varieties of tobacco and other crops grown in rotation with tobacco. These experiments indicate that for tobacco heavy applications of a complete fertilizer analyzing about 4-10-6 are most profitable. Experiments with varieties of tobacco indicate that the small strains of Orcnoco are best suited to the sun-cured section. Results seem to have proved conclusively that the most effective means of destroying the horn-worm on tobacco is with a proper application of arsenate of lead made with the most modern dust gun (Monarch). Other experiments pertaining to alfalfa made more recently by us seem to verify the theory that heavy applications of acid phosphate, lime and inoculation are essential to successful alfalfa growing in this section.

Holland, Nansemond County.—The main object of this station is to work with cotton and peanuts in rotation with other crops. These are the principal crops of this section of the State. A four-year rotation was selected consisting of cotton, corn, peanuts and soybeans, with corn and soybeans seeded to crimson clover to be turned down the following spring. Special attention is given to fertilizer work under cotton. Results thus far seem to indicate that acid phosphate has a tendency to cause hulls to form and mature earlier, also that nitrogen in very large quantities acts just the reverse way, and keeps the plant growing late, thus interfering with maturity before frost.

Variety work, also, is done with cotton. On account of the very short growing season for this crop in Virginia, it is desirable to use the variety which will mature in the shortest time. The long staple varieties of cotton have shown up very poorly up to this time. With peanuts, the greater part of the work is with lime and other substances containing calcium, which element, it seems, is a very important factor in giving the peanuts good weight and at the same time giving the hulls a light color which is very important when the crop is marketed. Several varieties are used, including Virginia Bunch, Virginia Runner, Jumbo, Valencia and Spanish.

Williamsburg, James City County.—Operations were begun at this station in 1912. Experiments are now under way testing methods of fertilizing alfalfa, both previous to seeding and as top dressing, liming, methods of cultivation and tests with varieties of alfalfa. The fertilizer tests have shown most strikingly the value of phosphorus in relation to alfalfa growing in this section. Acid Phosphate and barnyard manure, applied at the

rate of 10 tons of barnyard manure and 400 pounds of 16% acid phosphate per acre, have given the most satisfactory results. In all tests of fertilizers, from commercial sources, for alfalfa, phosphorus is shown to be the controling factor. Yearly top dressings to alfalfa with commercial fertilizer, early in the spring after the first season, have been found to greatly strengthen the plants, making the growth more rapid and dense, thereby keeping the ground shaded and preventing development of grass and weeds. It is not yet fully determined but we have reason to believe phosphorus to be the controlling factor in top dressing as well as in applications previous to seeding.

The tests with the varieties of alfalfa have been of great practical value to the alfalfa growers of this section. The behavior and finally the complete dying out of the Turkestan variety gives explanation for the majority of the failures in alfalfa growing in Eastern Virginia. The tests have shown the American varieties to be superior to any of the imported varieties, and of these the Kansas grown seed are giving the best results. The lime tests embracing the use of burnt and ground limestone, in varying amounts from one to four tons of burnt lime and from two to eight tons of ground limestone per acre, have as yet given no conclusive results in increasing the yield of alfalfa. Experiments are also being made to determine the relative value of leguminous crops turned in the soil as compared with barnyard manure as fertilizer for alfalfa.

Charlotte Court House, Charlotte County.—This experimental work was begun at Charlotte Court House six years ago, under the supervision of the Virginia Experiment Station, for the State Board of Agriculture. The site selected for the experiment plats was exhausted soil, being very poor and devoid of humus. Some of the land had been cultivated many years and had reached the stage where it would produce practically nothing. A good rotation was begun at once and by the use of a complete fertilizer to start the crops, followed by green manures and applications of lime, wonderful improvement as well as splendid results have been obtained. Special attention is given to tobacco culture in rotation with wheat, grass, corn and cowpeas.

In view of what had been done in regard to soil improvement, more land was taken up, this piece containing about 15 acres. This land has long been idle, and is characterized as worn-out soil, being much overgrown with bushes and broom-sedge. This land will be improved with green manure crops and by the use of acid phosphate and lime. The experiments carried on at this station have clearly demonstrated that the so-called "worn-out" lands of the region have great possibilities for agricultural use, and by judicious fertilization, soil management and crop rotation, these lands can be made productive and profitable.

Staunton, Augusta County.—This station is supervised by the Experiment Station for the State Board of Agriculture. The main lines of work are crop rotations, soil fertility and variety experiments. A five-year rotation of corn, soybeans, wheat and grass (two years) is used, on which an extensive series of fertilizer experiments is conducted. Especial attention is given to a comparison of different sources of phosphoric acid and nitrogen, and the various forms of lime. Another five-year rotation is used consisting of corn, wheat (two years), and grass (two years)—a rotation on which various mixtures of commercial fertilizers are tried in comparison with home-mixed goods of the same formulas.

Varieties of wheat and corn are being tried out. Rates and dates of seeding wheat and fall *versus* spring applications of fertilizers to wheat are being tested. The results of the work in alfalfa seem to justify the statement that it is more profitable to sow a light rather than a heavy rate of seed per acre, that is, about fifteen pounds instead of thirty. Also, that it is more profitable to sow alfalfa alone than in a mixture, and, that if alfalfa can be grown successfully, it is more profitable than any other hay crop. This experiment farm is favorably situated for the purpose, and should be of distinct service to agriculture in the Valley region of the State.

Martinsville, Henry County.—The work at this station is conducted by the Virginia Experiment Station for the State Board of Agriculture. Special attention has been given to a comparison of various crop rotations. There are three distinct rotation under comparison, namely, two-year, three-year, and five-year rotations. The two-year rotation consists of corn and cowpeas with crimson clover, rye and vetch seeded at the last cultivation of the corn. The three-year rotation consists of corn, wheat and sapling clover. A fertilizer test is conducted with each of these rotations and the results from both indicate that next to stable manure this soil needs acid phosphate.

The five-year rotation consists of corn, soja beans, oats, and grass (two years). This land receives no application of fertilizer, as the plats were arranged for the purpose of ascertaining the improvement of the land by the rotation of crops.

A number of variety tests are being conducted, including tests of corn, wheat, winter and spring oats, cowpeas, soy beans, and potatoes. This work has not yet progressed far enough to warrant the selection of certain varieties as the best for this section of the State. Sudan grass is experimented with in order to ascertain its adaptation to the locality, the best date and rate of seeding, and method of seeding. It grows well when seeded in rows about May 1, and cultivated. When seeded broadcast the weeds and foul growth choke it out. A small portion of land is devoted to the growing of unfamiliar crops for both their educational and practical

value. These crops include velvet beans, kaffir corn, shaller, peanuts, millet, buckwheat, rape, teosinte, sunflowers, sorghum, maize, feterita, and pop corn. On a much larger scale are grown fields of wheat, oats, barley, and rye.

Nine-tenths of an acre is allotted to determining the adaptability of alfalfa to this soil and climate. This was one of the first experiments installed and it has clearly and decisively proved that alfalfa is well suited to this locality. It has averaged a yield for the three years of 4,265 pounds on the nine-tenths of an acre. Several grass mixtures have been tried and the best results obtained from up-land seeding consisted of a mixture of Tall Oat Grass, Orchard Grass, and Medium Red Clover.

In addition to the other work at Martinsville, there is now in progress a reclamation project which has attracted considerable attention. This is an effort to reclaim for agricultural purposes a hill-side field that has long been idle. The land in question was thin, badly gullied, and partly covered with scrub pines and other undergrowth. The pines and brush were cut off and thrown into the gullies, the banks of the gullies were blown in with dynamite and leveled by hand labor. The land was partly plowed with a coulter plow to cut and break the roots remaining after the undergrowth was removed, and the remainder of the field was plowed with a turning plow. The entire tract was prepared and seeded to cowpeas. The object of this work is to accumulate data on the cost of putting a worn field into such shape that will permit the use of improved farm machinery. This experiment has progressed sufficiently to allow modern machinery to cross every gully. Failing to secure a good stand of grass in the fall of 1916, the land was thoroughly disced and rye was seeded over the entire area.

Animal Husbandry Department

Wintering Steers.—Feeding experiments were conducted to determine the best winter ration for steers, taking into consideration gains made on grass the following summer. The steers used were two-year-olds, divided into five lots of five steers each. Records of feeding experiments are available for three years, and are ready for publication at the end of the fiscal year covered by this report.

Supplemental Feed for Steers on Grass.—This experiment was undertaken in the summer of 1916. The supplementing of grass pastures with one, two, three and four pounds of cottonseed meal per head per day to three-year-old fattening steers on blue-grass pasture, showed that under the conditions prevailing this year, namely, plenty of rain which produced luxuriant growth of blue-grass, the cottonseed meal fed to the steers on grass was of no advantage whatever. For the steers receiving supplemental

rations of cotttonseed meal made smaller gains than the steers which ran in the pasture without any supplemental feed. It is not to be expected that this would prove true in a season unfavorable for pastures. The plan was to repeat this work in the summer of 1917, using different forms of concentrates for supplementary feeding, but it was not undertaken because of the unusually high price of feeding stuffs.

Wintering Dairy Heifers.—Studies are being made relative to the most economical winter rations for dairy heifers.

Dairy Husbandry Department

Protein and Energy Requirements for Milk Production (Adams Fund).—This project is being conducted co-operatively between the departments of dairy husbandry and chemistry. It was begun in 1913. At that time ten purebred Holstein cows were bought for the investigation and of the original herd, four are still being used on section (b) of this project, the remainder have died or have been sold. At the present time the herd consists of twenty-two females of all ages, eleven of which are cows in milk. There were no advanced registry cows in the original herd but at the present time there are six with very creditable seven-day records, and all the heifers that have freshened within the last two years have obtained advanced registry records.

About one-half of one wing of the dairy barn has been recently assigned to the Experiment Station for dairy husbandry research work, and this has been separated from the rest of the barn by a close partition. The fences and gates of the yards have been rebuilt and proper watering facilities installed. For the purpose of providing roughage, two silos have been built, a ninety-ton silo for winter feeding and a forty-five-ton silo for summer feeding. The stalls, feeding pens and boxes in the barn have been arranged conveniently for the digestion trials, and general feeding work of these experiments.

This project includes two lines of investigation.

SECTION (a). Protein and Energy Requirements for Milk Production: Experiments for the purpose of determining how much protein and net energy is required above maintenance to produce a definite quantity of milk. The results are to be expressed in terms of the ratio of the total protein of the food, less the maintenance protein, to the total protein of the milk produced; and of the net energy of the food, less the amount of net energy required for maintenance to the total energy of the milk produced.

In this work, six cows are used during each trial. These are divided into three groups and the animals are selected so that the groups are

balanced in respect to breed, age, plane of nutrition, weight, lactation period, œstrum period, amount of milk and persistency of milking. The treatment of these groups is at all times uniform, thus balancing conditions in this respect. A basal ration is fed to all the animals consisting of a mixture of palatable foods in which the ratio between the roughage and grain and also between the kinds of roughages and grains is alike for the groups. The basal ration supplies just enough digestible protein and energy for maintenance and milk production of the animals and is calculated separately for each individual according to its weight and amount of milk produced at the time.

To group I there is added to the basal ration one pound of protein in as pure a form as possible, blood meal being the substance used. To group II is fed one pound of carbohydrates in the form of corn starch in addition to the basal ration, and to group III the basal ration is fed alone.

The total feeding period extends over 150 days, which is divided into three 50-day periods. After each 50-day period, the groups are alternated and the basal ration readjusted. During the last 10 days of each 50-day period a ten-day digestion trial is conducted during which time the daily operations include the collecting and analyzing of the excrements, sampling and analyzing of the food, waste food, and the milk. From these data correction of the digestion coefficients of the individuals for the following periods is made and the increase or decrease of the weights of the animals is checked by aid of the nitrogen balance.

The work on this project was begun in the winter of 1912-1913, and since that time data on four complete trials has been secured. This data is being checked and tabulated and will be ready for publication next year.

Section (b). The Effects of High Protein and High Energy Rations on Feeding Dairy Cows: Through a study of the effects of high protein and high energy rations, information is sought relative to the effects on the physical condition of the cows that are used in the experiments, and the effects on the growth and development of the offspring of these cows, on the amount and composition of the milk of the cows and that of their offspring, on growth and milk production, and finally the effects of these rations on the metabolism of the animals under experiment. Two digestion trials have been completed and a report on the results of these trials is now in press. The high protein ration contains 7 pounds of gluten meal, 2 pounds of cottonseed meal, 2 pounds of bran, and 40 pounds of silage. The nutritive ratio of this ration is 1 to 2.4, and it normally contains much more protein than is necessary for maintenance and milk production. During the digestion trial the cow that was on this ration consumed only three-

fourths of the amount stipulated, but was still getting more than twice the necessary amount of digestible protein.

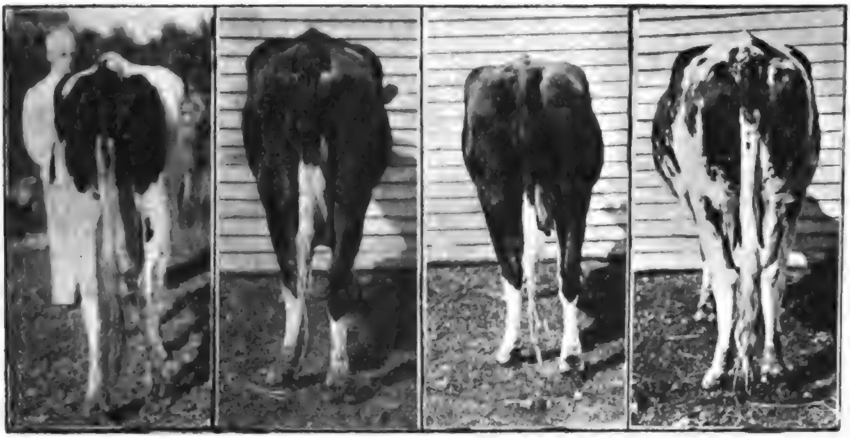


FIGURE 7—The two cows on the left were fed the high energy ration, those on the right the high protein ration. Note the poor condition of the cows on the left compared with the other two.

The high energy ration consists of 9 pounds of corn meal, 2 pounds of bran, and 40 pounds of silage. The nutritive ratio of this ration is 1 to 11.0. It contains enough digestible protein and about 45 percent more energy than is necessary for maintenance and milk production.

The continued feeding of these rations without intermission for over two years has not produced excessive fattening of the high protein cows, but these cows have maintained a rounded, well-fleshed appearance. The high energy animals on the other hand became extremely emaciated under the strain of milk production and could not maintain their weights until their milk flow almost ceased.

One animal from each group was selected for the digestion trial. Both of these animals were about at their minimum body weight when the trial was started and both gained weight after the trial. During the trial, the solid and liquid excrements were collected and analyzed daily and composite samples of the dung were made and analyzed as a check on the daily analyses. Composite samples of the milk were taken and analyzed for the whole period.

During the year, Technical Bulletin No. 12 was issued, dealing with "The Effects of High Protein and High Energy Rations in Feeding Dairy Cows." The following conclusions from the results of the digestion trial may be modified somewhat after other trials have been made.

. The cow that received the high protein ration was consuming only 75 percent of her ration, but this amount supplied her with sufficient energy and more than twice as much digestible protein (from average coefficients) as was necessary. The coefficients of digestibility of the protein, crude fiber and fat were all slightly below the average, but a large amount of protein in excess of the requirements for maintenance and milk production was digested. The coefficient of digestibility for the nitrogen-free-extract was slightly above the average. The cow that was fed the ration containing a large excess of energy consumed almost all of it, but it was found that the coefficients of digestibility of all the nutrients were reduced to a remarkable extent. The reduction of the digestibility of the protein, which, under normal conditions, was present only in sufficient quantity, caused protein starvation and consequent rapid loss of flesh when milk was being produced. The reduction of the digestibility lowered the energy of the digestible nutrients to an amount approximating the requirements for maintenance and milk production.

Plant Pathology and Bacteriology Departments

Black Rootrot of the Apple (Adams Fund).—Isolations from the affected roots of apple trees from a number of places in the State have yielded cultures of one or more species of Xylaria, a fungus genus of the Ascomycetes, not previously regarded as pathogenic. The cultures so obtained have been used for successful infections in the roots of apple trees with the production of typical symptoms of the disease and the recovery of the inoculum from the lesions. The results of this work, together with some field studies of the disease, have been published. A survey of the State which is in progress indicates that this disease is present throughout the commercial apple growing regions of the State and that in many places it is the most destructive single pest with which the apple grower has to contend. Studies are in progress regarding the resistance of rootstocks of Malus species and varieties to this disease.

The Relation between Parasitic Fungi and their Host Plants (Adams Fund).—The susceptibility of bean varieties to the rust fungus, *Uromyces appendiculatus*, is being studied. Some fifty varieties of beans are used and the work is carried on in the greenhouse under controlled conditions, supplemented by field studies. Wide variations in susceptibility have been found, some varieties being practically rust resistant, others very susceptible and others intermediate in susceptibility. This work is preliminary to studies of the fundamental basis of resistance.

The Nitrogen Compounds of the Soil as Affected by Bacterial Activities (Adams Fund).—Important progress has been made on this project.

Articles on different phases of the work are now in press, as follows: The effect of different plant tissues on nitrogen fixation; a study of the bacteriology of fresh and decomposing manure; the availability of limestone of different degrees of fineness. The work still under way consists of a study of the transformation of nitrogenous compounds in typical Virginia soils. This includes a study of ammonification, nitrification, nitrogen fixation, sulphofication and denitrification. The object is to determine whether there is any relation between the type of soil and its biological properties; whether the geological origin, for example, has anything to do with nitrification. Another object is to compare the biological efficiency of the different soil types.

Plant Disease Survey of Virginia (Hatch Fund).—A knowledge of the exact distribution and destructiveness of the numerous diseases of economic plants is necessary as a guide to the undertaking of practical research problems for their control. The work is conducted through correspondence and field trips, and the valuable accumulation of such data has been increased during the past year.

Field Experiments on the Control of Plant Diseases (Hatch Fund).—The control of apple foliage and fruit diseases is being studied, especially the value of dusting in comparison with spraying.

The study of alfalfa diseases has been discontinued, through lack of time and assistance.

No additional work has been undertaken on the control of cedar rust and this phase of the project has been discontinued.

The control of tomato blight (leaf-spot and late blight) through spraying was studied in continuation of previous work. The results of the past year were published in Bulletin 213, and showed a very satisfactory control of late blight with Bordeaux mixture, but little or no control of leaf-spot.

The Relative Susceptibility of Tomato Varieties to Disease (Hatch Fund).—This project is carried on in co-operation with the Department of Horticulture. Field notes on the susceptibility of some fifty tomato varieties to the Septoria leaf-spot disease have been obtained through three successive seasons. No one variety shows a high degree of resistance, but some are more susceptible than others. It is believed that control of the disease must be achieved through other means than varietal selection, but the use of the more resistant varieties should materially lessen the damage done by the disease.

Department of Entomology

The entomological experiments are in charge of the State Entomologist and are supported by funds of the Crop Pest Commission. The experi-

mental phases of the work, however, are closely affiliated with the Experiment Station.

The experimental work outlined in the previous report has been continued, especial emphasis being placed upon the study and control of fruit insects and upon the investigation of insect problems connected with the growing of truck crops. The orchard insects receiving attention are the apple aphids, which attack the foliage and fruit of the apple, and the woolly aphis, which is injurious mainly to the roots of young apple trees. It has been learned that by spraying apple trees with a contact insecticide at the time the leaf buds are swelling, injury by three species of aphids attacking the foliage may be prevented for that season. Reports from fruit growers indicate that injury by these leaf aphids has not occurred generally over the State, but mainly at certain localities, particularly in the neighborhood of Staunton, Augusta County, and in the region about Crozet, in Albemarle County. Fruit growers in these sections are advised to be on the lookout for these insects and to give prompt treatment when these insects are prevalent.

Control of Woolly Aphis (Schizoneura lanigera, Hausmann).—This problem has previously received attention by this department. For many years the life-history of this insect was imperfectly known, but recently it has been discovered that this aphis spends part of its life on the elm, and part on the roots of apple trees, and we are now in position to make an intelligent investigation of measures for its control. The resistance of various rootstocks to injury by this insect is being studied, and various remedial measures are to be tested.

Relation of Aphids to Spinach Blight.—The truck crop problem receiving most attention during the past year is spinach blight. This disease has become increasingly important during the past few years, and losses from it amount to thousands of dollars each season. It has been suggested that the disease was carried over the summer and spread from one spinach plant to another by certain insects, particularly the aphids attacking spinach, and during this year experiments have been conducted which demonstrate beyond question that this is true and that the aphids or other insects are carriers of the causal factor of the spinach blight. The problem is being continued and efforts are now centering on control measures. Spraying experiments are being conducted for the control of the aphids which transmit the disease, and many excellent results are accruing from co-operative experiments which are being conducted with spinach growers in the vicinity of the Truck Experiment Station, near Norfolk. It is hoped that the information gained during the coming season will be sufficient to enable the truckers to greatly reduce the amount of blight on their farms.

Inactive, Discontinued or Completed Projects

Studies of the Law of Inheritance in Garden Vegetables (Hatch Fund).

The Fertility of Virginia Soils (Hatch Fund).

Principles of Infection by Uredineous Fungi (Hatch Fund).

A Chemical and Bacteriological Study of the Different Methods Used in Measuring the Quality of Milk (Hatch Fund).

Legume Bacteria and Inoculation (Hatch Fund).

CO-OPERATIVE UNDERTAKINGS

Several of the departments of the Station are co-operating with other agencies in various lines of work. The Departments of Plant Pathology and Bacteriology are conducting a plant disease survey of the State in co-operation with the Bureau of Plant Industry, U. S. Department of Agriculture. The Agronomy Department is co-operating with the Office of Forage Crop Investigations of the U. S. Department of Agriculture in pasture management experiments. The Station is co-operating with the Bureau of Soils of the U. S. Department of Agriculture in a soil survey of Pittsylvania County, Virginia. The Station supervises the work at three County Stations supported by funds supplied by the State Board of Agriculture. The Station co-operates with the Virginia Crop Pest Commission on studies of apple aphids.

The closest co-operation is maintained between all the departments of the Station. It is often advantageous for men from two departments to work on the same problem, and this plan is followed when it is for the best interest of the Station as a whole.

AVAILABLE BULLETINS

Virginia Agricultural Experiment Station

Any or all of the following bulletins published by the Station will be sent free to anybody in Virginia who requests them so long as the supply lasts. If you are interested in farming, have your name placed on our mailing list to receive new bulletins as issued. Bulletins not listed here are now out of print.

FARM CROPS AND FERTILIZERS

Bulletin 166—Improvement of Fire-Cured Tobacco.
Bulletin 175—Tobacco Investigations.
Bulletin 180—The Blue-Grass of Southwest Virginia.
Bulletin 184—Impurities in Grass and Clover Seed Sold in Virginia.
Bulletin 196—Crop Rotation and Fertilizer Experiments with Sun-Cured Tobacco.
Bulletin 197—Growing and Curing Sun-Cured Tobacco.
Bulletin 198—Crop Rotation and Fertilizer Experiments with Bright Tobacco.
Bulletin 200—Chemical Studies of Virginia Soils.
Bulletin 202—The Immediate Effect on Yield of Crossing Strains of Corn.
Bulletin 204—The Management of Blue-Grass Pastures.
Bulletin 205—Summary of 10 Years' Experiments with Tobacco.
Bulletin 206—Experiments with Dark Tobacco.
Bulletin 207—Experiments with Alfalfa.
Bulletin 212—Sudan Grass.
Bulletin 214—Corn Culture.
Bulletin 216—Wheat Culture.
Bulletin 217—Potato Culture.
Bulletin 218—Peanut Culture.
Circular 1—Sugar Beets in Virginia.
Circular 3—Dates of Seeding Winter Grains.
Circular 4—Selecting Seed Corn.
Circular 5—Analyses of Sugar Beets in 1908.
Circular 6—Improving the Corn Crop.

LIVE STOCK AND DAIRYING

Bulletin 176—Hog Feeding.
Bulletin 178—Causes of Loss of Lambs in 1908.
Bulletin 182—Silo Construction.
Bulletin 186—Test of Hand Separators.
Bulletin 189—Some Diseases of Swine.
Bulletin 190—Co-operative Herd Testing.
Bulletin 199—Treatment of Bovine Tuberculosis.
Bulletin 211—Effects of Binders Upon the Melting and Hardness of Ice Cream.
Bulletin 215—Wintering Two-Year-Old Steers Preparatory to Finishing on Grass the Following Summer.

FRUITS AND VEGETABLES

Bulletin 155—Meteorological Data and Bloom Notes of Fruits.
Bulletin 177—Tomato Breeding and Varieties.
Bulletin 201—Preparation of Concentrated Lime-Sulphur Solution on the Farm.
Bulletin 203—Experiments on the Control of Cedar Rust of Apples.
Bulletin 208—Preparation of Nicotine Extracts on the Farm.
Bulletin 209—The Frog-Eye Leaf Spot of Apples.
Bulletin 210—A Stone-Fruit Spray Made from Hydrated-Lime and Sulphur.
Bulletin 213—Spraying and Dusting Tomatoes.
Circular 7—Fighting the Insect Pests and Diseases of Farm and Garden Crops.

Following are a few reprints for distribution:

The Outlook for Fruit Growing in Virginia.
Soil Management in Virginia Apple Orchards.
Spray Injury and Some of the Factors Which Favor It.

ANNUAL REPORTS

These contain the results of the more technical investigations and are not sent to farmers except on special request. Reports for 1908, 1909, 1910, 1911, 1912, 1913, 1914, 1915, 1916 now available.

Address correspondence to

AGRICULTURAL EXPERIMENT STATION,
Blacksburg, Virginia.

ANNUAL REPORT

OF THE

VIRGINIA POLYTECHNIC INSTITUTE

Agricultural Experiment Station

1917 - 1918

CONTENTS

The more popular and immediately applicable results of the work of this Experiment Station are presented in Bulletins and Technical Bulletins, which are for general distribution. This Report contains a brief statement of the work in progress and several Articles which are not published elsewhere.

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

1917-1918

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

LYNCHBURG, VA.
BROWN-MORRISON CO., INC., PRINTERS
1919

TABLE OF CONTENTS

ORGANIZATION

OF THE

VIRGINIA AGRICULTURAL EXPERIMENT STATION

STATION STAFF

J. D. EGGLESTON, A. M.	President
A. W. DRINKARD, JR. Ph. D.	Director
H. L. PRICE, M. S.	Horticulturist
W. B. ELLETT, Ph. D.	Chemist
†W. J. SCHOENE, M. S.	Entomologist
T. B. HUTCHESON, M. S.	Agronomist
F. D. FROMME, Ph. D.	Plant Pathologist and Bacteriologist
G. S. RALSTON, M. S.	Field Horticulturist
R. E. HUNT, M. S.	Animal Husbandman
C. W. HOLDAWAY, M. S.	Dairy Husbandman
H. H. HILL, M. S.	Associate Chemist
T. K. WOLFE, M. S.	Associate Agronomist
W. G. HARRIS, M. S.	Associate Chemist
A. B. MASSEY, B. S.	Associate Plant Pathologist and Bacteriologist
S. A. WINGARD, M. S.	Assistant Plant Pathologist
†R. R. REPPERT, M. S.	Assistant Entomologist
†L. A. STEARNS, M. Sc.	Assistant Entomologist
†G. W. UNDERHILL, M. Sc.	Assistant Entomologist
F. S. GLASSETT	Assistant Agronomist
C. F. WARREN, B. S.	Assistant Horticulturist
C. I. WADE	Treasurer
J. B. FOGLEMAN	Executive Clerk

COUNTY EXPERIMENT STATIONS

T. B. HUTCHESON, M. S.	Supervisor County Experiment Stations
W. W. GREEN (Bowling Green)	Supervisor Tobacco Investigations, and Superintendent Bowling Green Station
B. G. ANDERSON, B. S. (Appomattox)	Superintendent Appomattox Station
R. P. COCKE, (Williamsburg)	Superintendent Williamsburg and Lightfoot Station
*J. M. TRIMBLE, M. S. (Staunton)	Superintendent Staunton Station
J. C. HART, B. S. (Chatham)	Superintendent Chatham Station
*A. N. HODGSON, M. S. (Martinsville)	Superintendent Martinsville Station
*M. O. WILSON (Charlotte C. H.)	Superintendent Charlotte Station
E. T. BATTEN, B. S. (Holland)	Superintendent Holland Station

*In co-operation with the State Board of Agriculture. †State Crop Pest Commission.

Bulletins and reports are mailed free to all residents of the State who apply for them.

LETTER OF TRANSMITTAL

To His Excellency, Governor Westmoreland Davis:

SIR: In accordance with the Federal laws, approved March 2, 1887, and March 20, 1906, I transmit for your consideration the report of the Virginia Agricultural Experiment Station for the fiscal year ending June 30, 1918. It includes a brief statement of the work completed or in progress, and the principal changes which have occurred since the issuance of the last report.

Respectfully submitted,

A. W. DRINKARD, JR., *Director.*

February 1, 1919.

Annual Report

OF THE

Virginia Agricultural Experiment Station

1917-1918

By A. W. Drinkard, Jr., *Director*

President J. D. Eggleston,
Virginia Polytechnic Institute.

Sir: I submit herewith the annual report of the Virginia Agricultural Experiment Station for the fiscal year July 1, 1917, to June 30, 1918.

The Station has readjusted its programme as far as possible to meet the conditions of agriculture incident to the war, with the object of giving the most urgently needed assistance to the farmers. In some cases this readjustment required the delay of work on some of the fundamental experimental projects so that the efforts of the staff might be directed towards the solution of problems of more immediate practical bearing on agriculture. In these changes the guiding principle was to render the largest service to the State.

The Station co-operated actively with other agencies in furthering agricultural interests. It took some part in the important work of advising farmers along the lines of food production and conservation. Not only in Virginia, but throughout the United States, this campaign met with noteworthy success and the maintenance of normal production and often the increase in production of the staples of food and clothing under conditions of shortage in labor and fertilizers is an achievement of incalculable importance to the nation and to the cause of freedom for which this nation is striving in the world conflict.

PUBLICATIONS

During the year five bulletins were issued and sent to farmers in the State.

Bulletin No. 215—Wintering Two-Year-Old Steers Preparatory to Finishing on Grass the Following Summer. By R. E. Hunt. 15 pages, 2 figures, 3 charts. August, 1917.

Bulletin No. 216—Wheat Culture. By T. B. Hutcheson and T. K. Wolfe. 15 pages, 2 figures. September, 1917.

Bulletin No. 217—Potato Culture. By T. B. Hutcheson and T. K. Wolfe. 16 pages, 4 figures. December, 1917.

Bulletin No. 218—Peanut Culture. By E. T. Batten. 16 pages. January, 1918.

Bulletin No. 219—Wintering Dairy Heifers. By R. E. Hunt. 20 pages, 2 figures, 4 charts. April, 1918.

In February, 1918, the Annual Report was issued covering in detail the work of the Station for the fiscal year ending June 30, 1917. This report contained 39 pages and 7 figures, and its distribution was limited to persons interested in this information.

Bulletin No. 26, How to Prevent Smut in Oats, published by the Extension Division, in February, 1918, was prepared by Dr. F. D. Fromme. of this Station.

Members of the staff contributed various articles to the agricultural press during the year.

CHANGES IN THE STAFF

Mr. G. S. Ralston was appointed Field Horticulturist effective July 1, 1917. Mr. A. P. Moore, Superintendent of the Charlotte County Station, resigned, August 31, 1917, to enter military service, and Mr. M. O. Wilson was appointed in his stead. Mr. W. G. Harris, Associate Chemist, was granted leave of absence effective January 1, 1918, to enter military service. Mr. T. J. Murray, Associate Bacteriologist, resigned February 5, 1918, to accept a similar position at the Washington Agricultural Experiment Station, and he was succeeded by Mr. A. B. Massey, of the Alabama Agricultural Experiment Station on June 1, 1918. Mr. E. T. Batten, Superintendent of the Holland County Station, was granted leave of absence to enter military service June 1, 1918, and Mr. Joseph G. Holland was placed temporarily in charge of the Holland Station. Mr. R. E. Hunt, Associate Animal Husbandman, and Mr. C. W. Holdaway, Associate Dairy Husbandman, were promoted to Animal Husbandman and Dairy Husbandman, respectively, effective April 3, 1918.

FINANCES

Table 1 sets forth briefly the receipts and expenditures of the Station during this fiscal year. The Station received from the Federal Government $15,000 under the Hatch Act and $15,000 under the Adams Act. The Supplemental Fund is derived from the sale of farm crops, orchard fruits and live stock,—by-products of the experiments supported by Federal Funds, and the use of the Supplemental Fund is governed by the same rules under which the Hatch and Adams Funds are expended. All of the Federal funds are used at the main Station to support experiments and researches of a fundamental character bearing upon agriculture.

In the report of this Station for the fiscal year 1916-1917, p. 10, the need for increased support from the State Government was pointed out. The State Legislature, Session of 1918, granted substantial increase in its

appropriation to the Station. The annual appropriation for experiments with tobacco and crops grown in rotation with tobacco and for county experiment stations was increased from $16,000 to $20,000; and an annual appropriation of $10,000 was made under the provisions of chapter 226, Acts of the General Assembly of the State of Virginia, 1906. This law specifies that the appropriation shall be used for experiments, investigations and researches on agricultural problems with the view of advancing the agricultural interests of the State. This increase in the Station's support came at a very opportune time, because of the decreased purchasing power of money due to war conditions and it enabled the Station to maintain the experiments already in progress and to expand its work in several instances. This action on the part of the Legislature has been heartily commended by many forward looking farmers who realize the value and importance of the policy of aiding in the development of the agricultural resources of the State.

The State Board of Agriculture made the usual appropriation for the support of the County Stations at Staunton, Martinsville and Charlotte Court House.

PROGRESS AND RESULTS OF EXPERIMENTAL WORK UNDER EACH PROJECT

The progress and results of experimental work under each project are briefly outlined under departments in the pages which follow. These statements were summarized from the full reports of the heads of the several departments. Previous reports may be consulted for fuller details regarding plans and methods of work, as it is not deemed necessary to state these in every report.

Horticultural Department

Effects of Soil Environment on Fruit Bud Formation (Adams Fund)—The objects of this experiment and the plan of the work were fully set forth in the last report. The work progressed satisfactorily during the year. The peach trees in the orchard at Blacksburg suffered considerable winter injury, and it was necessary to head the trees severely in order to secure new wood. The peach trees in the orchard at Crozet yielded a fair crop of fruit. The apple trees have not fruited to any extent either at Blacksburg or Crozet. The experiments thus far indicate that cultural treatments have greater influence on the growth of apple trees and the growth and fruitfulness of peach trees than do fertilizers.

A separate orchard at Blacksburg is used to study the effects of pruning on fruit bud formation, and this phase of the work progressed satisfactorily during the year.

Table 1.—Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1917-1918.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS					
Appropriations	$15,000.00	$15,000.00		$20,666.66	$ 6,562.50
Balances from previous year			$ 4,049.68	1,864.27	1,356.28
Farm products, etc.			4,555.66	1,951.83	1,908.60
	$15,000.00	$15,000.00	$ 8,605.34	$24,482.76	$ 9,827.38
DISBURSEMENTS					
Salaries	$ 8,396.41	$ 9,073.01	$ 90.00	$ 8,992.51	$ 3,966.62
Labor	2,515.90	2,371.76	277.34	3,039.15	1,638.72
Publications	1,055.85		1,541.75	111.27	
Postage and Stationery	567.23		17.48	182.36	133.24
Freight and express	169.46	101.01	57.36	83.69	50.31
Heat, light, water and power	149.71	1.35	228.84		
Chemicals and laboratory supplies	42.71	363.24			
Seeds, plants and sundry supplies	615.51	423.90	157.93	511.01	739.86
Fertilizers	578.95	281.38	15.54	1,105.32	536.59
Feeding stuffs	61.42	1,425.09	1,045.93	243.31	98.00
Library	172.52		1.50		
Tools, machinery and appliances	126.86	91.56	67.94	796.17	700.56
Furniture and fixtures	89.11			81.33	2.98
Scientific apparatus and specimens	26.20	97.18	11.37		
Livestock	8.50	54.50	212.00	375.00	646.27
Traveling expenses	252.08	417.65	79.45	1,334.57	450.37
Contingent expenses	40.00			5.00	2.00
Buildings and land	131.58	298.37	76.72	777.60	486.12
Balances			4,724.19	6,844.47	375.74
	$15,000.00	$15,000.00	$ 8,605.34	$24,482.76	$ 9,827.38

Breeding Late Blooming Apples (*Adams Fund*).—The seedlings developed in this work have not yet fruited sufficiently to give enough information for determining their value. Owing to frost at the blooming period no additional hybridization was accomplished this year.

Commercial Value of Dwarf Apple Trees (*Hatch Fund*).—This experiment is now practically complete and the results were given in some detail in the last report. The dwarf apple trees are still under observation. The results indicate conclusively that dwarf apple trees do not fulfill commercial orchard requirements, yet dwarf apple trees have some value for special plantings. It was thought that dwarf trees would bear fruit at an earlier age than standard trees, but this experiment does not support this idea, and as a class the dwarf trees fruited no earlier than standards.

Variety Studies (*Hatch Fund*).—From the beginning of its work, the Station has given attention to the question of varieties. At present there are growing on the Station grounds many varieties of apples, peaches, grapes, gooseberries, currants, raspberries and blackberries. The behavior of varieties is observed also in different parts of the State. The object of this work is to secure for the benefit of fruit growers in the State authentic information regarding the value of different varieties. The information secured in these studies has enabled the Station to advise fruit growers regarding the selection of varieties and the advice given has done much towards the building of the commercial fruit growing industry in the State.

Soil Management and Fertilizer Experiments in Commercial Apple Orchards (*State Fund*).—This work is being carried out in commercial orchards at Winchester, Mt. Sidney and Cloverdale. The purpose of these investigations is to study methods of handling the soil and to determine the kinds and amounts of fertilizers that are needed to give best results in crop production. The work progressed in a satisfactory way during the year. Definite conclusions cannot be drawn from the experiments at this time; however, the results indicate that in general these orchards need nitrogenous fertilizers and respond very favorably to applications of this element. Phosphoric acid combined with nitrogen also seems to give paying results. No specific recommendations can be given to cover all cases. The condition of the trees is the best guide in determining the method of soil management and fertilizer treatment for a given orchard. When the trees show low vigor the need for nitrogen is apparently indicated.

Effects of Time of Pruning Apple Trees in Different Stages of Vigor (*State Fund*).—A series of pruning experiments was initiated this year to study several problems relating to the pruning of apple trees. Orchards are being used at Cloverdale, Harrisonburg, Linden, Shipman, Lovingston and Amherst. Commercial orchards in the State present many prob-

lems along the line of pruning and it is desirable to have information on questions of the best time to prune trees of various ages and degrees of vigor. It is hoped that these investigations will throw light upon the problems involved.

Effect of Time of Application and Sources of Nitrogenous Fertilizers on Tree Growth and Fruit Production (*State Fund*).—The application of commercial nitrogenous fertilizers to apple orchards has become quite general on many soil types in the fruit-growing districts of Virginia. Nitrate of soda and dried blood are the materials generally used to supply nitrogen for the purpose. The usual practice is to apply such fertilizers in the spring soon after the petals fall from the flowers. Apparently when applied at this time it does not increase the set of fruit the current season, although it is a benefit to the fruit which does set and stimulates tree growth. The object of this experiment is to determine the proper time for applying nitrogenous fertilizers to apple trees and to compare nitrate of soda and dried blood as sources of nitrogen for fertilizing the orchard.

Chemical Department

Fixation of Phosphoric Acid in Soils (*Adams Fund*).—The work was continued as in previous years. Soil samples were analyzed from the twenty-six plats by the N/5 nitric acid method. These plats receive phosphoric acid from different sources and in the same amounts, except where acid phosphate is used, in which case acid phosphate is used at the rate of 200, 400 and 600 pounds per acre. Corn has been grown continuously on these plats for eleven years and the object of the investigation is to correlate crop yield with the amount of phosphoric acid dissolved by the N/5 nitric acid method.

The effect of the addition of lime to one of the plats is very marked. The phosphoric acid content of the soil on this plat shows no increase according to the N/5 nitric acid test, but the crop yield from this plat continues to increase, showing that the beneficial effects of lime must be due either to an increase of phosphoric acid and potash available to the plant and not shown by the solvent or to a better physical condition of the soil resulting from the annual application of lime.

On a companion series of plats where wheat is grown continuously, the effect of annual applications of lime with and without manure, acid phosphate and floats, similar results are being found.

A study of the fixation of phosphoric acid by different soil types under controlled conditions in galvanized iron cylinders was continued.

Composting Phosphate Rock and Sulphur (*Hatch Fund*).—At the suggestion of the Agricultural Committee of the Council of National Defense,

the Chemical Department entered into co-operative arrangements for conducting experiments on composting raw rock phosphate and sulphur along lines proposed by Dr. Lipman of the New Jersey Agricultural Experiment Station. Soil previously inoculated with sulphofying bacteria, raw rock phosphate and sulphur were composted. Supplementary experiments were conducted with the addition of manure to the compost. Chemical analyses were made monthly during the past year showing that during this period of time 20 percent of the phosphoric acid in the raw rock phosphate was made available. Whereas in the compost without sulphur the availability of the phosphoric acid was not increased. The amount of phosphoric acid made available in the compost is not as high as that reported by other investigators; this may be due to the fact that the soil used in our experiments was not as favorable for the growth of the sulphofying bacteria as the soil used by other investigators.

The Effect of Green Manuring on Soils (Adams Fund).—This project is carried on in co-operation with the Agronomy Department. The work as originally outlined consisted of greenhouse, laboratory, pot and field experiments. Results of the greenhouse and pot experiments have been published, but as this work in the field experiments progresses certain points must be checked from time to time by these methods. The laboratory and field work is still in progress. At the present time the principal work under this project consists of two groups of field experiments.

The first group of field experiments has been under way since 1914 and a summary of the plan of work and results was given in the last annual report, to which the reader is referred.

The second group of field experiments deals with the effect of turning under green manuring crops at different stages of growth. These plats are 1/11 of an acre, one-half of each being cut for hay and the other half turned under. The green crops used are rye, oats, crimson clover and vetch. The first cutting is made on April 14, on alternate years and the last on June 15, when the crops have matured.

The first cuttings on these plats were made in April, 1916. Poor stands of grasses were obtained during this year, with the exception of rye which was cut and analyzed throughout the experimental period. About May 15, or four weeks after the cutting period had begun, samples of oats and vetch were obtained, while with the clover sufficient stands were not obtained until June 1 and June 15, the last two cutting dates. During the second week in June the plats were seeded to millet.

The stand of millet was especially poor on range B, on subplats 19A to 19H inclusive. These plats received vetch as a green manure treatment. Poor stands of millet were also obtained on range B, subplats 20A to 20D, 21A to 21E, and 22A to 22D. It may be said, in a general way, that the

Table 2.—Yields of Millet (all plats), 1916.

Range	Green manure crops	Average yield in tons per acre
B	Rye	1.057
B	Oats	1.796
B	Clover	1.932
B	Vetch	1.264
C	Rye	2.258
C	Oats	1.589
C	Clover	2.125
C	Vetch	2.254

material turned under prior to June 1 had little effect on the yield of millet. The material in the above plats in some cases contained a large percent of weeds. In other instances where the yield is low it is due to poor stand of millet, but the latter plats were usually free from weeds.

During the first week in October all the plats were seeded to wheat. The following summer (1917) the yields of wheat from all subplats were recorded. During the months of July and August (1917) the wheat stubble was fallowed for the purpose of preparing the soil for seeding the cover crops in August and September. The clover and vetch were seeded in August and the rye and oats in September.

At this early period of the experiment no marked differences in the yield of wheat were observed on the cut and turned plats, as the soil was perhaps adjusting itself to the new conditions of treatment, therefore no distinction has been made in the averages for wheat given in the table below. This method of stating results will be modified when the next wheat yields are recorded.

Table 3.—Yields of Wheat (all plats), 1917.

Range	Green manure crops	Average yield in bushels per acre
B	Rye	19.459
B	Oats	21.460
B	Clover	20.708
B	Vetch	16.468
C	Rye	19.127
C	Oats	16.444
C	Clover	13.736
C	Vetch	14.855

The chemical composition of the cover crops at various stages of growth is worthy of comment. There was a diminution of protein throughout the

cutting period with rye. The amount of protein present on April 14 was 21.59 percent, while on June 19, at the last cutting, it contained 5.49 percent.

There was a slight decrease in fat during this period but to no marked degree. Crude fiber was increased from 24.19 percent, at the first cutting, to 34.06 percent at the last, an increase of 9.87 percent. The carbohydrate increase was slightly above this; beginning with 42.11 percent in April and increasing to 54.52 percent on June 19, or 12.41 percent increase.

With the oats, very little change was noted in the composition of the crop on analysis. The most pronounced change was with the protein, which diminished between May 1 and June 19, 4.46 percent. The only other constituent to show a difference was the fat which increased 1.98 percent. Crude fiber and carbohydrates remained practically the same at all times.

Vetch and clover showed practically the same composition except a 5.50 percent diminution in protein for the former and a 5.34 percent diminution in carbohydrates for the latter. It must be remembered, however, that the stand of young grass was exceptionally poor and cuttings were begun as late as May 15, for vetch and on June 1 for clover, hence the first two cuttings from the former and the first three for the latter crops, were not taken. Therefore, it would not be wise to try to draw any definite conclusions from this small number of cuttings. This year (1918) full cuttings have been obtained on all grasses throughout the growing period to maturity. The land at this period (July) is ready for millet. It should have been seeded to millet earlier, but heavy rains the latter part of June prevented the seeding of this crop.

Agronomy Department

Cereal Investigations (*Hatch Fund*).—The work being done with cereals is a continuation of variety tests, the selection and testing of pure strains from the best commercial varieties, and culture experiments with corn and wheat. The results of the variety tests with corn and wheat have been reported in bulletins 214 and 216. The winter oats tests show Culberson and Virginia Gray to be the most resistant to winter killing, and the highest yielding commercial varieties at this Station. With spring oats, Silvermine, Welcome, Appler and Texas Rust Proof are showing up well. In the rye tests Abruzzi has proved one of the best for fall and early spring grazing, however, it is not quite so resistant to winter killing nor does it yield quite as well as Rosen. Both of these varieties are superior to the common winter rye usually seeded in this State. The best yielding

variety of winter barley has been Tennessee Winter. A variety of spring barley which gives a paying yield has not yet been found, nor have good results been obtained with either Speltz or Emmer.

Individual head selection work is being continued with wheat, oats, barley and rye. Wheat Selection 131 has now been in variety test four years, and has given an average yield per acre of three bushels more than the best bearded variety. Selection 112, a smooth type selected from Poole, has given a four-year average yield of twelve bushels more per acre than the parent variety, and eight bushels more per acre than any commercial variety in the tests. These selections are now being tested at all of the County Stations, and a limited quantity of seed from them is on hand at the central station for distribution to farmers. A selection of brown seeded winter oats found in a field of Culberson, is showing up well. It is very resistant to winter killing, and produces considerable winter pasturage. It also yields well. A limited quantity of seed from this selection is on hand for distribution to farmers. A selection from Dean rye had proved very resistant to winter killing. It has not been in the tests long enough for us to form an opinion of its yielding power. The cultivation experiments with corn and wheat were reported in bulletins 214 and 216. These experiments are being continued. Last year's results give the same conclusions as those reported in the above mentioned bulletins.

Pasture Management (Hatch Fund).—This project was completed and discontinued at the end of the last grazing season. This work shows briefly that very light grazing is injurious to blue grass sod, while heavy grazing improves the sod and eradicates obnoxious weeds. Top dressing blue grass sod with farmyard manure, or acid phosphate, improved the sod and increased the grazing capacity. Acid phosphate gave the most economical increase. Lime applied to acid soils improved the sod. Harrowing and disking sods failed to improve them, except where soils were bare and new grasses were seeded. Results on the use of chemical sprays to kill weeds are being reported under the head of Eradication of Field Hawkweed.

Pasture Clipping Experiments (Hatch Fund).—This work was outlined to determine the effects of different fertilizer mixtures on the chemical composition of pasture grasses, and to determine the relative yields of different pasture grass alone and in mixtures. The plats in this experiment are being clipped with a lawn mower whenever long enough to graze, and notes are taken on yield and chemical composition of the clippings obtained. This experiment has not been running long enough to justify any conclusions.

Forage Investigations (Hatch Fund).—Variety tests are being conducted with cow peas and soybeans. No variety of cow peas has been found that gives profitable yields of either grain or hay in this locality.

Soybeans do well here wherever the soil is well inoculated. Hollybrook, Haberlandt and Wilson are among the best varieties yet tested here. Millet, buckwheat, sudan grass, clover and vetch are being tested for yield of hay. An experiment on rates and method of seeding soybeans was started in the spring of 1918, and an experiment with rates of seeding red clover, timothy and red top was started in the fall of 1917. Some work with rates of seeding and fertilization of white and yellow sweet clover was commenced in the spring of 1918.

Potato Experiments (*Hatch Fund*).—The experiments with potatoes have been continued as outlined. The results to date were published in bulletin 217. Several selections obtained by the "tuber unit method" have out-yielded commercial varieties in experiments extending over eight years.

Alfalfa Experiments (*Hatch Fund*).—The alfalfa experiments started in 1914 show that alfalfa is an extremely uncertain crop at Blacksburg. The chief soil requirements of the crop seem to be an abundance of organic matter, lime and phosphorus. The rates of seeding tests, fifteen to twenty pounds of high germinating seed have given best results, while dates of seeding from July 15 to August 15 have been most successful. Top dressing of phosphorus and farmyard manure have lengthened the life of the stand and increased yields economically. Cultivating the crop with an alfalfa cultivator has kept out the blue grass and improved the stand of alfalfa. These cultivations should come before the crop begins growth in the spring and after any cutting. In the variety tests Kansas grown common alfalfa shows up best so far.

Lime Experiments (*Hatch Fund*).—These tests were outlined to determine the best form of lime for a rotation of corn, wheat and grass. The tests have been going on for three years, and they do not indicate any significant difference in the value of burnt lime, ground lime-stone and marl when applied in equal quantities of calcium oxide per acre. In connection with this project some pot experiments are being conducted in the greenhouse to determine the best degree of fineness for ground lime-stone for agricultural purposes.

Fertilizer Tests (*Hatch Fund*).—Some experiments were commenced in the fall of 1917 to determine the best place in a rotation of corn, wheat and grass to apply manure, lime and acid phosphate. These experiments will also test the relative efficiency of manure, lime and phosphates when applied in small quantities often and larger quantities at longer intervals.

Rotations (*Hatch Fund*).—The two, three, four and five year rotations are being continued as outlined, except that the plan has been revised so as to bring a crop of wheat on all of the land every sixth year to test the increased or decreased fertility of the soil.

Silage Experiments (Hatch Fund).—This experiment is conducted in co-operation with the chemical department and is designed to test the so-called silage varieties of corn against those sorts ordinarily planted for grain, both in yield and in percentage of digestible nutrients; to find out the relative feeding value of silage made from corn at different stages of maturity; and to find the relative total amounts of digestible nutrients produced by corn and other crops used for silage purposes. At the present time these experiments indicate that corn is superior to all other crops tested for silage, both in total tonnage produced per acre and total digestible nutrients. And that the so-called silage varieties of corn, such as Cocke's Prolific, produce a silage lower in percentage of protein and fat than the grain varieties, such as Boone County White, but when the total amount of protein and fat produced on an acre are considered, the ensilage varieties lead, since they produce a much greater tonnage per acre.

Fertilizer and Green Manuring Experiments (Adams Fund).—These experiments are in co-operation with the department of chemistry and are reported under that department.

Some Principles Governing Growth and Maturity of Corn (Adams Fund).—Some phases of this work have been completed, others are being continued and new phases of the investigation are being started. In the study of the Effect of High and Low Soil Moisture on Growth and Maturity of Corn, the average of three years' results in regard to maturity and two years' results in regard to yield, show strikingly that the critical time in the life of the corn plant so far as moisture requirements are concerned is in the early stages of growth. The corn plants which grew in soil held at 70 percent of saturation made the largest yield. These same plants matured practically as soon as the plants grown under any other conditions, with the exception of the plants which grew in soil where the moisture was alternately high and low. The plants of this latter series matured three days earlier than any other series of plants, and yielded second only to the series grown entirely under optimum moisture conditions. There was but little difference between the time of maturity of plants grown with optimum soil moisture to tasseling and those grown with sub-optimum amounts to tasseling, but the yield was decidedly in favor of the former. This fact also holds true for the plants grown under optimum soil moisture conditions for the first six weeks and under sub-optimum conditions for the same period, the difference in yield is not as pronounced.

In the series where the moisture was sub-optimum throughout the period of growth, the yield was greatly reduced, while the effect in the time of maturity was not pronounced. Allowing plants to undergo a period of wilting reduced the yield but the effect on maturity was not marked. The first year's results of this experiment are reported in techni-

cal bulletin 14. The conclusions drawn from the average of the three years' results are essentially the same as those reported in technical bulletin 14. This portion of the project has been completed.

Investigations were continued on the Effects of Hybridization on Maturity and Yield of Corn, and the results secured in 1917 were in close accord with those secured in 1916, and were so striking that it was not deemed necessary to continue this portion of the project. The results of the first year are reported in technical bulletin 18. The conclusions drawn from the average of the two years' results are the same as those reported in technical bulletin 18. Briefly, the hybrids matured earlier and yielded more than the parent varieties.

There seems to exist no relation between time of germination and time of maturity of early germinating kernels and late germinating kernels from either early or late germinating ears. This conclusion is drawn from the results of experiments covering a period of three years. In case of early germinating ears, the plants produced by the early germinating kernels produced more dry matter, as shown by a two year average, than the late germinating ears. Also, the dry matter produced by plants from kernels from the late germinating ears was greater in amount than that produced by the plants from kernels from the early germinating ears.

In the study of the relation between the time of germination and time of maturity of different ears within a single variety, a number of correlation coefficients have been calculated. Data have been collected to determine these same correlations for 1917 and the crop planted to secure similar results for 1918. In order to secure more conclusive results along this line, the time of tasseling and silking of a number of plants was observed in the field and the time of germination obtained for the ears produced. These data are at hand and will soon be compiled.

Data have been collected for three years on the effect of different commercial fertilizers, lime and manure on the maturity of corn and wheat. In 1918 the effect of root and leaf pruning and of different somatic factors on maturity and yield will be noted.

The County Experiment Stations (State Funds)

There are nine County Stations, three of which are financed by the State Board of Agriculture, located at Staunton, Charlotte Court House and Martinsville; and six are financed from State appropriations, and are located at Holland, Williamsburg, Bowling Green, Lightfoot, Appomattox and Chatham.

The chief reasons which led to the adoption of the policy of establishing county experiment stations were first, the comparative inaccessibility to many farmers, of the main station at Blacksburg; and secondly, the great differences in soil types and climatic conditions in the several re-

gions of the State, which make it impossible to do experimental work on all crops at the same place. Annual field days are held at the county stations when large numbers of farmers assemble to avail themselves of the opportunity to become acquainted with the experiments and to hear lectures on timely agricultural subjects.

Chatham, Pittsylvania County.—Work at the Chatham Station was begun in 1908, and has followed the same general plan outlined in earlier reports. The work consists largely of fertilizer tests with the use of lime, variety work, and five one-acre plats are used as demonstrations in the proper fertilization, seeding and cultivation of tobacco, wheat, grass (two years) and corn. One acre is used as a demonstration plat in growing alfalfa.

The fertilizer experiments are conducted on 1/20 acre plats, lime being applied every fifth year on half of each plat. The rotation on these plats consists of tobacco, wheat, mixed grasses (two years) and corn, with rye seeded on the corn stubble as a green fallow for tobacco. No fertilizer is applied to any crop except tobacco, and in this way the residual effects of the fertilizers used on the tobacco crop are noted through the succeeding crops. The outstanding feature of the work has been the results from the use of acid phosphate, and on all crops except tobacco, lime has given remarkable results. Lime gives an increase in yield of tobacco but usually a decrease in proceeds. This rule did not hold good in 1917, however, due to the high price for common grades of tobacco, and in 1917 a substantial increase in the proceeds from the use of lime was secured. The comparison of the different sources of ammonia has shown a marked variation. Materials composed of quickly decaying organic matter, such as dried blood and cottonseed meal gave uniformly best results. Wood ashes are being tested this year as a substitute for commercial potash.

In the fall of 1918 plats were laid out and variety tests were begun on a fairly comprehensive scale. Previous to this time very little had been done along the line of testing varieties of the leading farm crops for this section. Four varieties of winter oats, two of rye and fifteen of wheat were seeded and the following spring six varieties of spring oats, eight of potatoes (with three repeated as late crop potatoes), ten varieties of corn, and ten varieties of cow peas were planted. Five one-acre plats are used to illustrate the application of fertilizers to tobacco and other crops grown in rotation with tobacco. These plats are run through a regular rotation, and serve a very useful purpose in showing the farmers of this region the best methods of cultivating and fertilizing their leading crops.

One acre is used as an alfalfa demonstration. Alfalfa is succeeding fairly well at this place and gives promise of being a valuable hay crop for farmers in this region.

Appomattox, Appomattox County.—The work at this Station was altered somewhat during the past year. The old fertilizer tests were discontinued and the results obtained from them will be reported at an early date. These tests show that phosphorus is the limiting element of plant food in crop production, and that for tobacco a fertilizer containing 5% of nitrogen and 8% phosphoric acid and 4% potash gives best results. The use of potash does not materially increase the yield, but the quality of the crop is improved and profitable returns are obtained from its use when potash prices are normal. Experiments on the use of fertilizers with tobacco and crops grown in rotation with tobacco are being carried on. One-half of each plat is limed at the rate of 1,000 lbs. burnt lime or its equivalent, before clover each year. All other fertilizer is applied to the tobacco crop. The chief object of this experiment is to compare the value of acid phosphate alone with acid phosphate in combination with other elements as a fertilizer for tobacco. This experiment was started in the spring of 1918.

A rotation experiment is in progress to determine the best rotation from a crop production and soil improvement standpoint for local conditions. Two, three and four year rotations, using the chief crops of this section, are being compared as to profitableness. These tests were started in the spring of 1918.

Variety tests are in progress, including corn, tobacco, wheat, oats, rye, cow peas and soybeans. These tests will be continued until suitable varieties for local conditions are determined. Considerable attention is being given to alfalfa experiments. Varieties of alfalfa have been under observation here for several years. The present indications are that Kansas grown alfalfa seed give best results. Seed production tests are being carried on with the Kansas grown variety.

Bowling Green, Caroline County.—The United States Department of Agriculture, in co-operation with the Experiment Station, undertook certain experiments at this place in 1908, which have been continued to the present time. In these experiments especial attention has been given to fertilizers, cultural methods, combating insects, varieties of tobacco, corn, wheat, oats, peas, soybeans, alfalfa, and to crop rotations.

These experiments have established some important factors by the results obtained from the applications of fertilizers and lime. The leading results of this experimental work are now being demonstrated on one-acre plats each year with satisfactory and profitable results. The fertilizer test with tobacco shows that for sun-cured tobacco an application of 1,000 to 2,000 lbs. of a fertilizer analyzing about 3% nitrogen, 10% phosphoric acid and 5% potash, is the most profitable, the nitrogen being supplied from nitrate of soda and dried blood, each furnishing equal parts. All fertilizer tests have shown that phosphoric acid is the dominant fac-

tor in growing any crop in this section, and that nitrogen and potash cannot be economically applied unless phosphoric acid is also applied. Variety tests including about thirty varieties of tobacco have shown that when considering both quality and quantity the small, or narrow leaf strains of Oronoco are best. The most effective way of combating the tobacco horn worm is by an application of three to four pounds of powdered arsenate of lead per acre, applied with the Monarch Dust Gun. Our experiments with alfalfa show that inoculation of the soil and application of acid phosphate and stable manure are essential to securing a successful stand and growth of this crop during the first fall, winter and spring, and that heavy applications of lime are essential to a successful stand for a long period of years.

All experiments with lime indicate that after rotating and turning under heavy crops of stubble and green fallow, lime is a most important factor in economically and permanently building up the soil fertility. Other experiments started more recently with the important varieties of corn, wheat, oats, peas, soybeans and potatoes, have not been conducted long enough to justify a conclusive statement relative to their yielding values, although interesting results are developing.

Holland, Nansemond County.—The chief features of the work at this Station are fertilizer experiments with cotton and peanuts. The results of fertilizer experiments with peanuts were reported in bulletin 218. However, this line of work is being continued. The cotton experiments show that phosphorus and potash must both be applied for good crops of cotton, but that nitrogen may be maintained by a rotation in which a legume is brought on the land every other year. Lime gives paying results both by sweetening the soil for the crop to which it is applied, and by making it possible to grow larger crops to plow under,—thus increasing the organic matter of the soil.

In the forage crop experiments velvet beans, sweet sorghums and soybeans are showing up well. Permanent meadows made of timothy, clover and red top are giving profitable returns. Alfalfa culture has not been successful, owing to the lowness of the land.

Variety tests are being conducted with cotton, peanuts and soybeans. In these tests Trice cotton, Haberlandt and Mammoth soybeans, and Jumbo peanuts have been showing up well. Variety tests of corn, cow peas, wheat, oats and rye are being conducted for the first time this season.

Williamsburg, James City County.—The work at this station consists mainly of experiments in alfalfa. The projects are being continued as outlined. The results to date show that alfalfa is a highly profitable crop in this section, and that it is easily grown if lime and organic matter are sup-

plied and a well balanced complete fertilizer is used. The fertilizer tests show that phosphorus is the limiting element of plant growth in this section.

Excellent results have been obtained from top-dressing old stands of alfalfa both with farmyard manure and commercial fertilizers. From present indications it seems that alfalfa stands may be maintained in this section if the crop is fed by the addition of plant food each spring. Farmyard manure as a top dressing for alfalfa has given paying results, and has not increased the growth of weeds. Cultivation of the alfalfa crop has not been found profitable where Bermuda grass is prevalent, since the breaking of the underground root stocks of this plant seems to increase its vigor.

Forage crop experiments are being conducted with soybeans, crimson clover and vetch, all of which are showing splendid results. Experiments with sowing Japan clover in wheat or oats in the spring indicate that a good crop of forage for either hay or pasture may be obtained the same year by this method.

Variety tests are being conducted with corn, wheat, oats, rye, soybeans, cow peas and potatoes. Reports will be made on the results of these tests from time to time.

During the summer of 1917 some experiments were carried on to determine the profitableness of raising hogs on pasture in this section. When crops were sown so as to give good pasturage throughout the summer, hogs were raised very profitably. Rye, crimson clover and soybeans seemed to be some of the best annual crops for hog pasture. Hogs are being run on alfalfa this summer to determine both the amount of gains made on this crop and the effect of grazing on the alfalfa sod.

Lightfoot, York County.—On November 1, 1917, a farm was leased here for the purpose of conducting experiments with alfalfa and various other farm crops grown in this section, and for experiments along the lines of pasture for hogs. Little more was done this year than to begin preparations for establishing experimental work on this new location.

Charlotte Court House, Charlotte County.—The work at this county station is supervised by the Virginia Experiment Station, and financed by the State Board of Agriculture. Work at this station consists chiefly of fertilizer experiments with dark tobacco and other crops grown in rotation with tobacco. Variety tests have been introduced during the past year and some reclamation work has been started. The results of fertilizer experiments at this station are in harmony with those obtained at the other county stations, and show that phosphorus is the limiting element of plant growth, but that for tobacco a complete and readily available fertilizer gives best results. When the prices of potash are normal a fertilizer con-

taining 5% of nitrogen, 8% phosphoric acid and 4% potash, gives the most profitable returns. The source of nitrogen should be some quickly available organic material, such as dried blood or it should be nitrate of soda. The fertilizer used was in the form of 16% acid phosphate and the potash was in the form of sulphate of potash. Lime gives paying results in connection with tobacco when applied to some preceding crop in the rotation, but lime has a tendency to make a low grade tobacco when applied directly to the tobacco crop. Nitrate of soda has paid well as a top dessing on both wheat and grass.

Variety tests are being carried on with wheat, oats, rye, corn, potatoes, tobacco, cow peas and soybeans. These variety tests are being conducted for the first time this season. A reclamation project has been undertaken for the purpose of determining the best method and the cost of reclaiming typical worn-out land. In this work a piece of land was selected that was badly washed and grown up in scrub pines and broomsedge. The first year this land was cleared, plowed, leveled and sowed to cow peas. The cow peas were fertilized with 400 lbs. 16% acid phosphate per acre, and they made a luxuriant growth under this treatment. They were turned under during the fall of 1917, and rye was seeded on the land. In the spring of 1918 the rye was turned under and cow peas were again seeded on the land. The peas will be cut off for hay and the land seeded to a mixture of orchard grass, tall oat grass, red top and red clover in the early fall of 1918. The land will be limed at the rate of one ton burnt lime per acre and 400 lbs. 16% acid phosphate will be applied at the time of seeding the grass. Account is being kept of all expenditures and receipts from this project, and check plats are being conducted to determine the rate of improving the land.

Staunton, Augusta County.—This county station is supervised by the Virginia Experiment Station, and financed by the State Board of Agriculture. The first project deals with one acre demonstration plats on which a practical demonstration is made of the best results obtained from the fertilizer tests that are carried on at this station. At present 16% acid phosphate is the only commercial fertilizer being used on these demonstration plats, with light applications of stable manure on the second year grass. The crops on these plats have been satisfactory.

The second project consists of five ranges of plats, each range containing 21 plats. The ranges are cropped in a five year rotation of corn, soybeans, wheat, grass, and grass. Various fertilizers are applied to the soybeans, wheat and first year grass, according to the original outline. The wheat plats gave rather an unusual result this year. Every plat that received nitrogen, either from nitrate of soda or sulphate of ammonia, was

far superior in appearance to those that received no nitrogen. This is contrary to past experience, since we have found previously that the nitrogen plats have seldom been much ahead of those without nitrogen.

The third project deals with alfalfa culture. Some difficulty was experienced in securing a stand of this crop on account of the plants freezing out on some of the plats. The plats are being cropped in corn at present and will be reseeded to alfalfa at a later date.

The fourth project consists of a test of fertilizer mixtures. The object of this experiment is to try various commercial mixtures in comparison with home mixed fertilizers of the same formulas. It is conducted on a range of 19 plats, ½ of each plat being used as a check. The range is cropped in a five-year rotation of corn, wheat, wheat, grass, and grass. The fertilizers are applied twice in this rotation, before the corn and the second year wheat. This experiment has been in progress three years and no marked results have yet been obtained.

The fifth project is a test of wheat varieties, rates of seeding and dates of seeding, and a spring application of fertilizers in comparison with a fall application. These tests are being made on bottom land and give promise of useful and practical results.

The sixth project is a miscellaneous test of varieties of farm crops for this section. In this test are included four varieties of winter oats, six varieties of spring oats, two varieties of winter rye, sixteen varieties of corn, sixteen varieties of soybeans and cow peas, and ten varieties of potatoes.

Martinsville, Henry County.—This county station is supervised by the Virginia Experiment Station, and financed by the State Board of Agriculture. The work at this station is being conducted along the lines previously reported, except the changes noted in this report. The fertilizer tests show that the soil in this region is noticeably deficient in organic matter and phosphorus, but it has ample supply of potash for immediate use. When legumes are grown in short rotations and organic matter is added to the soil, acid phosphate seems to be the only fertilizer needed for profitable crop production.

Comprehensive variety tests were begun during the year. These include a test of cereals, legumes and potatoes, in a three year rotation. The first year the land is seeded to small winter grains, followed by cow peas after the grain is harvested. The second year potatoes are planted on the land, or corn and other cultivated crops, which are followed by rye. The third year consists of a test of legumes, such as cow peas, soybeans, velvet beans and peanuts. A legume experiment was also started this year to determine the legume which gives the quickest returns in this region. Five plats, each ¾ acre in size, were planted to velvet beans, soybeans, crimson

clover, cow peas and winter vetch. These crops will be left on the land until spring, when all will be plowed under and the entire tract of land planted to corn. The corn will be fertilized with 400 lbs. acid phosphate per acre.

Another experiment was started to test the value of Farmogerm as a fertilizing material. Farmogerm was applied to millet and kaffir corn. It is hoped to give this material a more complete test next year.

An experiment was started to determine the cost and practicability of reclaiming worn-out land in this section. The plan of the experiment is to plant corn on the land without any fertilizer being applied. This gives a test of the yielding capacity of the soil. The corn crop is followed by several green manure crops which are turned under, after which corn will be planted again. An accurate cost account will be kept of all expenses connected with this project.

Another experiment was started this year to determine the best time and method of seeding grass. Grass mixtures are seeded at different times during the season and under different methods of handling the soil.

Animal Husbandry Department

Wintering Steers (Hatch Fund).—The results of the experiments carried on under this project were published in Bulletin 215. No additional work was undertaken on this subject because of the high price and scarcity of feeds.

Wintering Dairy Heifers (Hatch Fund).—The results of the experiments under this project covering two years were published in Bulletin 219.

Self Feeders for Dairy Cows (Hatch Fund.)—Experiments and observations on this project were made during the year and the results of this work are given in a separate paper in this report. In brief these results show that self feeders are not economical for feeding dairy cows, but the contrivance is useful in testing the palatability of feeds for dairy cows.

The Price of Milk and its Food Value (Hatch Fund).—Under this project studies are being made to show the correlation between the price of milk and its food value.

Advanced Registry Testing (Supplemental Fund).—The owners of the cows tested bear the expense of this work. The advanced registry work has increased rapidly during the year. Tests were made of seven Holstein-Friesian herds comprising 64 cows; ten Jersey herds comprising 121 cows; and thirteen Guernsey herds comprising 46 cows. Fourteen supervisors were employed in this work. In addition to paying the supervisors, the owners of these cows also pay a nominal fee for every cow entered, in order to cover the cost of clerical labor required to handle the records at this office.

Proposed Experiments.—During the next year, it is proposed to undertake experiments on sheep breeding, milk substitutes for feeding dairy calves, pastures for hogs, and wintering dairy heifers.

Dairy Husbandry Department

The work in this department, which is conducted jointly with the Chemical Department, consists of three phases, all dealing with the protein requirements in animal feeding.

Protein and Energy Requirements for Milk Production (Adams Fund).—A large amount of data have been accumulated bearing on this project and these data are now being tabulated. No further work was attempted during the past year, but at the request of the Agricultural Committee of the Council of National Defense, our efforts were devoted to an emergency project dealing with the maximum and minimum protein requirements for the growth of calves, this work being in co-operation with Dr. H. P. Armsby of the Pennsylvania Institute of Animal Nutrition.

The Physiological Effects of High Protein and Low Protein Rations on Dairy Cows (Adams Fund).—This experiment was begun in 1913 with two groups, each containing two cows. The progeny of these cows have been placed on the respective rations after weaning, the females being kept in the herd and the males sold after remaining on the experimental ration twelve months. Three of the original cows are still in the experiment; three female progeny have been added to the herd and data has been recorded for four males.

The effects of high and low protein rations are considered in four different relations, namely, the effects on the health of the cow and offspring; on growth and development of the offspring; on the composition of the milk and yield of milk; and on the metabolism and general utilization of the nutrients in the rations. The rations fed to the cows are standard in amount throughout the lactation periods, and therefore vary somewhat during these periods in the relations between the nutrients supplied and the nutrients required. They are designed to supply the necessary energy for maintenance and milk production for cows producing 20 lbs. of milk daily, but the high protein ration contains about twice as much digestible protein as is necessary, and the low protein ration barely meets the requirements for protein. These two rations, therefore, are representative of wide and narrow rations,—the ratios being 1:2.4 and 1:11.

Results have been reported in Technical Bulletin 12 on the part of the work dealing with the utilization of the nutrients of the rations. To obtain these results a digestion trial was made with one cow from each group, and the data secured were so significant that a second test was made with the remaining cows to test the accuracy of the preceding work. This second

trial will show that the conclusions drawn from the first trial are fully borne out in the second trial, particularly with respect to the more important points. The decrease in digestibility factors for the low protein cow was as marked as before. For the high protein cow the factors were average, as before. In this trial also the high protein ration seemed to favor the production of a large quantity of milk fat from substances other than food fat. The increase of milk fat over available food fat in the first trial was 100% and in the second trial 70%.

The Maximum and Minimum Protein Requirements for the Growth of Calves (Adams Fund).—As previously noted this project is being conducted co-operatively with Dr. Armsby, of the Institute of Animal Nutrition, at the Pennsylvania State College, and the plan of the work was suggested by Dr. Armsby. A productive ration must contain digestible protein at least equal to the maintenance requirements, plus the amount of protein contained in the product. Some recent investigations indicate that at least moderate production may be secured with rations containing a little more digestible protein than the minimum just indicated. Other investigations, on the contrary, seem to show that a much more liberal protein supply is at least advantageous, if not necessary, and the current feeding standards for growing animals accord with this view. In most of these investigations little or no attention has been paid to the quality of the proteins consumed, to the influence of accessory substances (vitamines), or to variations in the ash of the ration.

The general plan of this experiment is to place either beef or dairy calves, old enough to be fed dry feed exclusively, upon two different planes of protein intake, but with equal net energy supply. The low protein ration is to supply little more than the minimum amount of protein, theoretically required, while the high protein ration is to supply about the amount demanded by current feeding standards. The energy supply is intended to be as much as will support normal growth, but not cause fattening. The proteins of the two rations are to be derived in fixed proportions from identical feeding stuffs and an ample supply of ash ingredients and vitamines is to be assured. Any necessary adjustments in the bulk of the ration are to be made by variations in the amount of straw and necessary adjustments in the energy supply by the use of greater or smaller amounts of commercial starch.

Four-grade Holstein-Friesian calves were purchased in January, 1918, for this experiment. The feeding period was started in March, but the calves had been fed a preliminary ration consisting of the same feeds as outlined in the experiment. On May 16, a digestion trial was conducted on all these animals. This trial lasted ten days. The results of this experi-

ment will be correlated with those obtained from other experiment stations, and with the results of our other feeding trials.

Plant Pathology and Bacteriology Departments

Black Rootrot of Apple (*Adams Fund*).—This disease which has been shown by our previous work to be due to species of Xylaria is being carried as a major problem of the department. Some thirty strains of the fungus have been isolated from diseased apple roots from different parts of the State, and their culture characters on different nutrient media have been determined. None of these strains has produced ascospores in these cultures, although a wide variety of media has been employed. The failure to obtain ascospores in cultures has made the determination of the species involved particularly difficult, since the identification of the Xylarias rests largely on the characters of the ascospores. This difficulty has been overcome in part by the establishment of cultures from ascospores taken from fruiting forms of Xylaria collected in the field. Comparisons between these cultures from ascospores and those previously obtained from mycelium from diseased apple roots has made possible the assignment of some of the latter to either *Xylaria polymorpha* or *X. longeana.*

The remainder and larger part of these strains from apple roots represent a single species district from either of the foregoing and one which cannot be assigned with certainty to any of the named species of Xylaria. They were at first thought to be *X. hypoxylon,* but later work proved this incorrect. It is hoped that additional collections of fruiting forms will clear up the status of this doubtful species.

Inoculation studies on young apple trees have involved measurements of the rate of terminal growth of inoculated and check trees, and studies on the character of the root infection. The soil at Blacksburg seems to be somewhat unfavorable for the development of rootrot. It also appears that the time of year when the inoculation is made may determine the success or failure of infection. Inoculations have also been made on self-rooted varieties of apple for the purpose of testing the relative susceptibility of the different root systems. Field studies on methods of dissimination and on the development of the disease with reference to the type of soil and condition prior to planting are being continued. Several striking instances have been found where the disease is much more destructive on "newly cleared" land than on "old" land.

The Relation between Parasitic Fungi and their Host Plants (*Adams Fund*).—This is largely a study of the resistance of varieties of beans to the bean rust fungus (*Uromyces appendiculatus*). The work of the past year has been confined to greenhouse studies, using certain refinements of

methods designed to provide uniformity in inoculation. A standard dosage has been developed together with a superior method of determining resistance. Some seventy varieties of the common bean, *Phaseolus vulgaris,* have been studied and this phase of the work is practically complete. Wide variations in the susceptibility of varieties have been found. While the greater number of varieties are found to be moderately or slightly susceptible, some are very susceptible and some practically immune or rust resistant. As a class, the green podded varieties are more susceptible than the wax podded varieties. These greenhouse tests are being supplemented by field trials during the present season. A preliminary study of certain physical and chemical properties of the sap of resistant and susceptible varieties gave no clue to the probable basis of resistance. This work will be pushed as soon as time permits.

Nitrogen Compounds of Soils as Affected by Bacterial Activities (Adams Fund).—The work of the year involved a comparative study of ammonification, nitrification, nitrogen fixation, sulphofication, and denitrification in typical Virginia soils. About three-fourths of the surveyed areas of the State have been covered by the work to date, but the results have not been tabulated and no conclusions can be announced at this time. This practically completes the project as planned and no further work on these lines is contemplated.

The Relative Susceptibility of Tomato Varieties to Diseases (Hatch Fund).—The work has been continued as in previous years. The Septoria leaf-spot was the only disease of importance which occurred during the season. No variety was found to be resistant, but some were much more susceptible and suffered much greater losses than others.

Field Experiments on the Control of Plant Diseases (Hatch Fund).—The spraying experiments on the control of tomato diseases have been continued. These have been developed for the present season into a co-operative experiment between the Bureau of Plant Industry of the United States Department of Agriculture and this Experiment Station. The introduction and test of a variety of tomato which is resistant to the Fusarium wilt disease is also being conducted under this co-operative plan.

A leaf spot disease of tobacco which was prevalent in the flue-cured belt, has been undertaken as a special study. A bacterium has been isolated from the diseased tobacco leaves, and its pathogenicity has been proven by a series of inoculation in the greenhouse. The organism is apparently undescribed and a report on the etiology and pathology of the disease has been prepared for publication.

Plant Disease Survey (Hatch Fund).—The occurrence of an important disease of wheat within the State has been brought out through the survey work. This disease is caused by a nematode (*Tylenchus tritici*). The in-

festation occurs in the head and as a rule all of the grain in the affected head is destroyed. Fully half of the grain in one field was destroyed by this pest and other fields with losses of 20 per cent to 25 per cent have been seen. Although the disease is apparently rare in the United States, having previously been reported from but four states, it is said to be common and destructive in Europe. Our records show that it is present to some extent in four counties in the State. Rockingham, Fauquier, Fluvanna and Albemarle. A special survey of the State to determine the extent of the infestation is planned for the immediate future, in co-operation with the central office of the Plant Disease Survey.

Department of Entomology

The entomological work is in charge of the State Entomologist. The experimental phases of this work, however, are closely affiliated with the Experiment Station. The experimental work outlined in the previous report has been continued with the addition of three new projects. The project, "Control of Woolly Aphis, (*Schizoneura lanigera Hausmann*"), is now receiving special attention. This insect is causing serious losses in many parts of the State. The various remedial measures are being tested in orchards.

The Oriental Peach Moth (*Laspeyresia molesta*).—A special field laboratory has been established in Loudoun county with headquarters at Leesburg, for the purpose of studying the life history and if possible ascertaining a method for the control of this new pest. The oriental peach moth is now known to attack apples as well as peaches, and will probably be referred to in the future as the "fruit moth." The insect is not definitely known to exist in Virginia outside of Fairfax and Loudoun counties; it is suspected elsewhere, and will soon be an additional pest in Virginia orchards.

Insects attacking Corn, Cotton and Tobacco.—This project has been inaugurated for the purpose of collecting information regarding the principal pests of these crops, with a view to making detailed studies of those new or little known, and of determining the most practical remedies for such insects as the corn ear worm, the corn stalk borer, and others which are now causing extensive losses.

Insects attacking Alfalfa and Clover.—Due to the work of the county agents in many sections of the State, the number of acres of these two crops is being gradually increased, and the fields more carefully scrutinized with the results that pests of alfalfa and clover are being reported more frequently than heretofore.

The entomological work, which is being conducted in coöperation with the Truck Experiment Station at Norfolk, has been continued along the lines reported in 1917. The problem, "*Relation of Aphids to Spinach*

blight," has received the most attention. The control of the insects attacking spinach is being studied. Various insecticides have been used alone and in combination with fungicides. The combination sprays have given the most satisfactory results. For young spinach a combination of nicotine sulphate, fishoil soap and a 0.10 percent solution of copper sulphate has rendered the most effectual control for aphids and downy mildew (*Peronospora effusa*). Satisfactory results have been derived by spraying the fall crop of spinach. The problem confronting us at the present time is the control of the aphids between January 1 and April 1.

The strains of selected spinach varieties and hybrids which have shown some resistance to blight have been carried through the third year. Seed was saved from 132 individual selections this year. Many of these were crossed with Savoy, Manchuria and Manchuria hybrid stocks. In seed production, the Norfolk Savoy-Manchuria hybrid, F_2, outyielded the pure Norfolk Savoy nearly 200 percent.

Experiments and studies have been conducted relative to the life history of the pink and green aphid of potato (*Macrosiphum solanifolii*). The importance of this is becoming greater each year. At the present time, through its agency in the transmission of spinach blight and by its direct injuries to potatoes and spinach, it is a menace to an industry valued at twelve or fourteen million dollars.

CO-OPERATIVE UNDERTAKINGS

Several departments of the Station are coöperating with other agencies in various lines of work. The department of Plant Pathology and Bacteriology is conducting a plant disease survey of the State, in coöperation with the Bureau of Plant Industry, United States Department of Agriculture. The coöperative experiments on pasture management were completed during the year; these experiments were conducted by the office of Forage Crop Investigations of the United States Department of Agriculture and the department of Agronomy of this Station. This Station is coöperating with the Bureau of Soils of the United States Department of Agriculture in a soil survey of Pittsylvania County. This Station supervises the work at three County Stations which are supported by funds supplied by the State Board of Agriculture. The Station coöperated with the Virginia Crop Pest Commission in several lines of experimental work. The Station coöperates with the Extension Division of the College in many ways to promote the agricultural interests of the State.

The closest coöperation is maintained between the several departments of the Station. It is often advantageous for men from two departments to work on one problem and this plan is followed when it is for the best interests of the Station.

ERADICATION OF FIELD HAWKWEED

By T. B. Hutcheson and T. K. Wolfe.

Field hawkweed (*Hieracium pratense*) is fast becoming a serious pest of pastures in Virginia. Especially is this true in the southwest section of the State, where this weed has already gained much headway in the bluegrass pastures.

Description

Field hawkweed is a small plant, one to two feet tall, unbranched, erect, and covered with short black hairs. The stem is without leaves, except an occasional bract. The leaves of the plant which are hairy on both sides, are clustered around the base, forming a dense mat which smothers out other

Fig. 1—Showing dense character of growth of hawkweed plants.

plants, among which the weed is growing. The showy yellow flowers are borne in a cluster at the top of the stem. Only a few of the flowers open at one time; the remainder of the cluster consists of buds in various stages of growth. The flowering period extends from June to September. The plant is a perennial and has two methods of reproduction; namely, by seeds and by runners or stolons.

The bad reputation of field hawkweed is due to the rapidity with which it spreads, and to the fact that the mat formed by the leaves is so dense that it kills other plants among which it once becomes established (Fig. 1). The plants spread from one field to another or from farm to farm, by seeds which are carried by the wind (Fig. 2). Besides dissemination by means of seeds, the plants are propagated rapidly by means of runners (Fig 3). This latter method of reproduction is the same as that found in the strawberry. The runners take root and produce new plants (Fig. 4). The new plants in turn send out runners, and as a result other plants are crowded out in a remarkably short time. The roots are fibrous and intermingle, forming a dense mass (Fig. 5). Large pieces of hawkweed sod can be removed intact just as can bluegrass sod. Animals dislike the plant, either in the green or dry state, because of the hairs which cover all parts of the plant, and because of its bitter juices.

Experiments to Control or Eradicate the Pest

In 1915 this Station undertook in a limited way some measures in an attempt to control or eradicate the field hawkweed. In the spring of 1917 this Station, in coöperation with the U. S. Department of Agriculture,

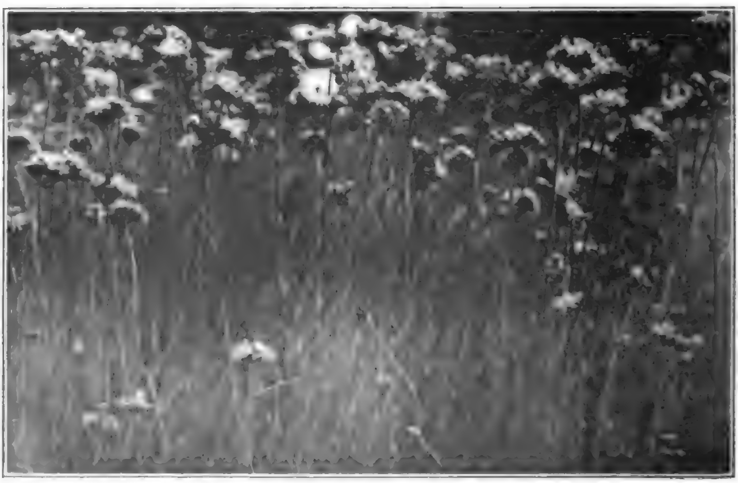


Fig. 2—Showing character of hawkweed flower and seed production. The downy seeds are readily disseminated by the wind.

began some more extended investigations in an effort to secure an effective and practical means of destroying the pest without permanent injury resulting to the grass.

The materials used were sodium arsenite, one-fifth pound to one gallon water; nitrate of soda, three pounds to one gallon water; dry salt, 4,000 pounds per acre; salt solution, three pounds to one gallon water; fuel oil, undiluted; and dip oil, one-half gallon to one-half gallon water. All of the solutions were applied in the form of a spray at the rate of 150 gallons per acre. Each of the solutions and the dry salt were applied at thirty-day intervals, beginning with May 1 and ending with October, thus making six applications. At the time of later applications, the plants which had been previously treated, were again treated in case any hawkweed were present. In this way it was possible for the plat treated for the first time on May 1 to receive six treatments during the season, the plat treated for the first time on June 1 five treatments during the season, etc. At the same time that the different materials were applied, the weeds were cut from a corresponding plat with a hoe. Notes were taken during the season of 1917 and on June 4, 1918.

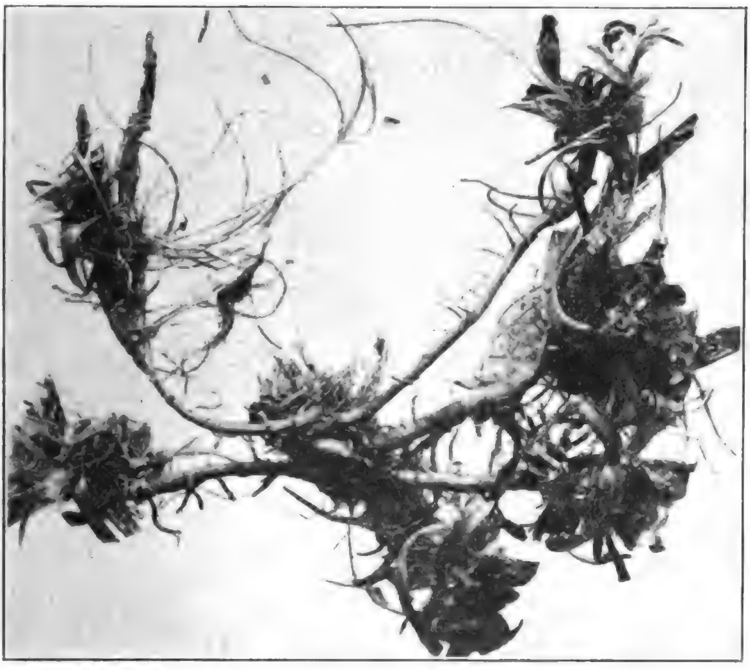


FIG. 3.—Showing how hawkweed is propagated by means of runners which take root and give rise to new plants located several inches from the parent plant.

Notes on Control and Eradication

In Table 1 data are presented showing time of spraying, materials used, rate of application, and the final notes made in 1918 on the results of the different treatments.

Table I.—Materials used, rate of application and 1918 notes on results of the treatments.

Date of application	Sodium Arsenite—⅛ lb. to 1 gallon water. 150 gallons per acre.	Nitrate of soda, 3 lbs. to 1 gallon water. 150 gallons per acre.	Dry salt, 4,000 lbs. per acre.	Salt solution, 3 lbs. to 1 gallon water. 150 gallons per acre.	Fuel oil, undiluted, 150 gallons per acre.	Dip oil, ½ gallon to ½ gallon water. 150 gallons per acre.	Weeds cut with hoe.
May 1........	Practically no hawkweed. Very good stand grass.	Few hawkweed. Very good stand grass.	Practically no hawkweed. Fair stand grass, but many bare spots.	Few hawkweed. Very good stand grass.	Many hawkweed. Stand grass only fair, but better than original.	Many hawkweed. Good stand grass.	Abundant hawkweed. Stand grass fair, about same as original.
June 1........	Practically no hawkweed. Very good stand grass.	Few hawkweed, more than previous plat. Very good stand grass.	Practically no hawkweed. Good stand grass.	Few hawkweed. Very good stand grass.	Many hawkweed. Good stand grass.	Many hawkweed. Good stand grass, but not so good as previous plat.	Abundant hawkweed Grass poor, not good as original.
July 1........	Very few hawkweed. Very good stand grass, but not so good as two previous plats.	Fairly large number hawkweed. Very good stand grass, but not so good as previous plat.	Practically no hawkweed. Only fair stand grass, many weeds present.	Few hawkweed. Very good stand grass.	Many hawkweed. Good stand grass.	Few hawkweed. Very good stand grass.	Many hawkweed. Practically no grass.

Aug. 1........	Very few hawkweed. Good stand grass.	Many hawkweed. Good stand grass.	Practically no hawkweed. Only fair stand grass. Many weeds.	Many hawkweed, especially around edge. Good stand grass.	Many hawkweed. Good stand grass.	Few hawkweed. Very good stand grass.	Only a few hawkweed. Practically no grass, but new grass starting.
Sept. 1........	Few hawkweed. Fairly good stand grass, but better than original.	Many hawkweed. Fair stand grass, but better than original.	Practically no hawkweed. Good stand grass.	Many hawkweed. Good stand grass, but poorer than Aug. 1 plat.	Many hawkweed, especially in spots. Fairly good stand grass.	Few hawkweed around edge, more than on Aug. 1 plat. Good stand grass.	A few more hawkweed than on Aug. 1 plat. Practically no grass but new grass starting.
Oct. 1........	Many hawkweed. Grass no better than original	Many hawkweed. Fairly good stand grass.	Few hawkweed present in patches, probably missed on applying salt.	Many hawkweed. Good stand grass, but poorer than Sept. 1 plat.	Many hawkweed. Fair stand grass but slightly better than original.	Many hawkweed. Stand grass only fair, but better than original.	Same amount of hawkweed as on Sept. 1 plat. Practically no grass, but new grass starting.

From a study of Table 1, it is found that sodium arsenite completely killed the hawkweed when repeated sprayings were made during the season. However, when only one spraying was made (October 1) many hawkweed still remained. Sodium arsenite injured the grass slightly, but the grass entirely recovered before fall. In fact the grass was greatly improved. *Sodium arsenite is a deadly poison and stock should not be pastured on grass surveyed with this material until it has been completely washed off by rain.* One application of this spray did not kill the weeds, and it was necessary to repeat the sprayings each month.

Repeated sprayings with nitrate of soda solution gave good results, but inferior to sodium arsenite. Nitrate of soda solution injured the grass slightly, but it recovered quickly and the following spring the grass was greatly improved. One application of the spray did not kill the weeds, and it was necessary to respray each month.

FIG. 4—New hawkweed plants which originated from runners.

Dry salt was very effective in killing hawkweed; very few plants appeared after the salt had been applied once. At the same time, all other vegetation was killed and did not reappear to any great extent until the following spring. At this time the stand of grass was from fair to very good on the different plats, and on all plats better than the original stand. It seemes that hawkweed can be effectively killed by a single application of

dry salt in the late fall, and the grass will appear in good condition the following spring. Thus, late fall applications of dry salt are more advisable than earlier ones. This is reverse to the treatments with sodium arsenite and nitrate of soda.

When salt solution was used, repeated applications were necessary to kill the weeds. The solution also injured the grass which did not recover to any great extent until the following spring. In regard to injury to grass and effectiveness in killing hawkweed, the early repeated sprayings gave better results as compared with late fall applications. This is in agreement with the sodium arsenite and nitrate of soda treatments, but reverse to the dry salt treatment. Applications of salt solutions were not as effecive in killing hawkweed as applications of dry salt, but the former did not injure the grass to the same extent.

Applications of fuel oil kindled both the weeds and grass. However, repeated treatments were necessary to hold the weeds in check. The grass was slow in returning, and even in the following spring the stand on the different plats was fair to good. The oil apparently killed the above ground portions of the plant without serious injury to the underground parts. From the results obtained, the use of fuel oil in combating hawkweed is not to be recommended.

The use of dip oil was but little more practical for killing hawkweed than the use of fuel oil. Repeated sprayings were necessary to hold the weeds in check, and then they appeared again the following spring. But, as in the case of fuel oil, the grass did not appear in any great amount until the following spring.

In this experiment, on the May 1 and June 1 plats, on which the weeds were cut with the hoe, the grass sod was disturbed as little as possible. On the other dates the entire plats were chopped. This method as practiced in this experiment did not give good results. The plats on which only the weeds were removed have an abundant amount of hawkweed and the stand of grass has either deteriorated or failed to improve. On the plats where the treatment was more severe, the hawkweed have been more successfully destroyed but the grass was also killed. No doubt if these plats had been plowed and planted to some intertilled crop, such as corn, and kept cultivated for one season, the hawkweed would have been successfully eradicated.

Summary

Proper applications of either sodium arsenite, nitrate of soda, salt solution, or dry salt were effective in controlling hawkweed without permanent injury to Kentucky bluegrass.

Fig. 5—Showing dense mat of fibrous roots under a heavy turf of hawkweed.

Applications of fuel oil and dip oil, and the method of removing weeds with the hoe as practiced in this experiment, were not satisfactory in controlling hawkweed.

Dry salt was the most effective material used for destroying hawkweed. However, the grass did not recover until the following spring.

Repeated applications of sodium arsenite solution was nearly as efficient in killing hawkweed as dry salt, and the grass recovered much more quickly. However, sodium arsenite is poisonous.

Repeated applications of nitrate of soda solution were inferior to repeated applications of sodium arsenite solution. However, the former solution gave good results and the grass recovered rapidly.

Five to six applications of either sodium arsenite, nitrate of soda, or salt solution were necessary at intervals throughout the season to hold hawkweed in check. A single application of dry salt in the late fall has given good results.

THE FERTILIZATION AND MANAGEMENT OF BLUE-GRASS PASTURES

By T. B. HUTCHESON AND T. K. WOLFE

At the present time many requests are being received by the Experiment Station for information concerning the advisability of applying fertilizers to bluegrass pastures. The experiments recorded in this bulletin bring out some important points in regard to fertilizers for pastures and their management.

In the western portion of Virginia there are about twenty counties where agricultural income is derived largely from bluegrass pastures. Many of the pastures in this section of the State have not been plowed for many years. Some of them have never been cultivated, the grass having come on naturally after the land was cleared. It requires several years to secure a good bluegrass sod, but after the sod is obtained, if it is properly grazed and cared for, the grass improves with age. However, there are many acres of pasture lands which are not as good as formerly. Many of these pastures are too steep and rough to be plowed, while others suitable for general farming yield such a large income from grazing that it is not practical to cultivate them. It is for such pastures as these that information as to the practicability of the use of fertilizer is needed.

The soil in the bluegrass section of the State is of limestone origin, which produces grass of high feeding value. (For detailed information as to the composition of bluegrass, see Virginia Experiment Station Bulletin 180). Each year from this section thousands of finished steers are sold from pastures without any additional feeding. Export cattle can be produced only on the best pastures, and in this type of bluegrass farming the gain per individual animal is of the first importance. On the other hand many thousands of acres of bluegrass pastures are used to produce lighter cattle for local consumption or for grazing dairy cattle, and in this class of bluegrass farming the total gain per acre is of main consideration.

In order to study certain phases of the management of bluegrass pastures, the Virginia Experiment Station in 1908 started a series of experiments in coöperation with the Office of Forage Crop Investigations of the United States Department of Agriculture. The results of the first five years of this investigation are reported in Virginia Experiment Station Bulletin 204.

In this paper alternate and continuous grazing are compared, the data on the effect of certain cultural treatments on bluegrass pastures are presented, light grazing is compared with heavy grazing, and the eradication of weeds is discussed.

During the last five years (1913-17) of the experiment the cultural treatments were discontinued and in their place certain fertilizer applications were made. Wherever possible the results of the last five years will be combined with those of the first five years, in order to make them more conclusive. The same fields were used throughout the ten years, the pasture consisting of a bluegrass and red top sod growing on a limestone soil. The writers cannot say whether results similar to those reported in this bulletin would be secured on other grasses or types of soil.

Plan of the Experiments

Twenty acres of old limestone pasture land at Blacksburg, Montgomery County, Virginia, that had not been plowed for at least twelve years prior to the beginning of the experiment in 1908, were surveyed, divided, and fenced in eight two-and-one-half-acre fields. Each one of the plats extends about two rods into a piece of woods, in order to give the animals shade. The ground in the woods had very little grass on it, and was not counted in the area of the pasture plats. A watering system was installed to furnish fresh water in every field. These fields were numbered one to eight, inclusive. There were communicating gates between fields one and two, three and four, and five and six. Platform scales, upon which to weigh the animals, were placed near the fields.

In 1913 and 1914 heifers were used, and were divided into three groups of three each, one group of two and one group of only one. While in 1915-1917, two-year-old steers were used, and were divided into four groups of two each, and one group of one.

Treatment of Fields.—Field No. 1 received an application of 10 tons of manure to the acre in the spring of 1913. This was the only application during the five years. Field No. 2 was untreated to serve as a check on field No. 1. The same group of animals was changed every two weeks from one of these fields to the other.

Field No. 3 received an application of 300 pounds of 16 percent acid phosphate per acre in the springs of 1913, 1915 and 1916. The same animals were alternated every two weeks between field No. 4 which was untreated, and field No. 3.

Field No. 5 received an application of 250 pounds of bone meal per acre in the springs of 1913, 1915 and 1916. The same animals were alternated every two weeks between field No. 6, which was untreated, and field No. 5.

Fields Nos. 7 and 8 were not fertilized and were grazed continuously through the summer. Field No. 8 was grazed twice as heavily each season as field No. 7. However, during the years 1909, 1910, and 1912, field No. 7 was grazed twice—one season three times—as heavily as field No. 8.

Alternate Grazing Compared with Continuous Grazing

It is sometimes recommended that pastures be given periods of rest during the grazing season. It is supposed that by this alternate grazing the grass will make maximum growth and allow a large number of animals to be carried on a given area. This practice will require more fences and the gain in the number of animals carried or the gains made by the animals, should be sufficient to pay for the extra fencing and the trouble of changing the stock from field to field.

In Table I the results of experiments covering a period of eight years show a comparison of alternate and continuous grazing.

Table I.—Comparison of alternate with continuous grazing.

(1909, 1910, 1912-1917.)

		Total gain, lbs.
Alternate grazing	Field No. 2	2371.25
	Field No. 4	1764.00*
	Field No. 6	2719.25
	Total gain	6854.50
	Average gain per field	2284.83
Continuous grazing	Field No. 7. Grazed lightly continuously	2084.5
	Field No. 8. Grazed heavily continuously	2751.0†
	Total gain	4835.5
	Average gain per field	2417.75
	Difference in gain in favor of continuous grazing	132.92

On fields Nos. 2 and 4, from 1909 through 1912, three animals were grazed alternately every ten days; on field No. 6 every twenty days. During 1913 and 1914 three animals were grazed alternately every two weeks, and during the years 1915-1917 two animals were alternated every two weeks.

During the years 1913-1917, field No. 7 was grazed continuously with one animal. During this same period, field No. 8 was grazed continuously with two animals.

The difference in gain is in favor of the continuous system of grazing. However, the difference is not great, because this constitutes the total

*In 1915 the cattle grazing on field No. 4 were removed on account of sickness and no weights were secured from this field for that season.

†In 1913 one of the heifers was removed on account of sickness and no weights were included for that season.

gain for a period of eight years. Since this length of period has been covered, the results clearly show that alternate grazing is not to be recommended without qualification.

Effect of Fertilizers on Bluegrass Pastures

In recent years there has been a very noticeable deterioration of some of the pastures in certain sections of the State. The carrying capacity of the pastures has been lessened and numerous weeds have made their appearance. The effect of certain fertilizers in certain crops in different portions of the State is marked. However, the experimental data in regard to the use of fertilizers on bluegrass pastures are limited. In order to secure results along this line some experiments were conducted at Blacksburg as previously noted in this paper. The results of these experiments are shown in Table II.

Table II.—Results of fertilizer treatments. Gain of steers (pounds) on two-and-one-half-acre fields under different fertilizer treatments.

	Group I		Group II		Group III			
Year	10 tons manure per acre	Not manured	300 lbs. acid phosphate per acre	No fertilizer	250 lbs. bone meal per acre	No fertilizer	Number steers in group	Length of grazing period—days
1913	260.5	345.5	185.0	174.0	188.0	120.0	3	83
1914	334.0	239.0	220.0	160.0	252.0	359.0	3	143
1916	417.75	230.25	551.0	261.5	383.5	486.5	2	168
1917	413.0	142.50	399.0	127.5	374.75	246.75	2	142
Totals	1425.25	957.25	1355.0	723.0	1198.25	1212.25		
Gain or loss	468 pounds gain		632 pounds gain		14 pounds loss			

The results secured in 1915 are omitted because the steers in group II were removed during the latter part of the season on account of sickness. From a study of Table II it will be seen that the animals grazing on the manured field made larger gains in three out of the four years. The manure was applied in the spring of 1913, and during that year the animals did not eat the grass as readily on the manured as on the unmanured field. It would probably have been better to have applied the manure the preceding

fall. However, the larger total gains made by animals on the manured field is about sufficient to pay for the manure applied. At the same time some benefit from the manure would be expected for several years longer.

The animals grazing on the field to which acid phosphate was applied made larger gains in all four years than they did on the unfertilized field. These gains were substantial, being sufficient to pay for the fertilizer and its application and besides leaving a good profit.

In case of the bone meal applications there was a slightly larger gain made on the unfertilized field. This gain was so small as to be within the limit of experimental error. It is rather difficult to say why bone meal failed to give good results, while acid phosphate did. Bone meal is often recommended for grass as the plant food is more slowly available than that in acid phosphate and a benefit will be derived from it for several seasons. In this instance acid phosphate has given markedly better returns.

In the bluegrass section of Virginia, as well as in all parts of the State, the great need of the soil is phosphorous in a readily available form, as contained in acid phosphate.

Light Grazing Compared with Heavy Grazing

In the sections of the State from which steers are fitted for the export market on bluegrass alone, three to five acres of pasture are allowed to each animal. When stockers are grown or dairy cattled grazed, the pastures are much more heavily stocked. Whether pastures should be grazed lightly or heavily will depend upon the type of bluegrass farming adopted.

Table III.—Gain (in pounds) of steers continuously grazed on two fields, each field containing two and one-half acres.

Year	Lightly grazed field		Heavily grazed field		Length of grazing period in days
	Number of animals	Total gain (all animals)	Number of animals	Total gain (all animals)	
1909	1	255	2	488	138
1910	1	328	2	648	164
1912	1	235	2	349	150
1914	1	186	2	243	143
1915	1	151	2	230	140
1916	1	371	2	415	168
1917	1	288	2	378	142
Total gains..........		1814		2751	

In order to secure data on the total gains made from heavy and light grazing, and the effect on the sod, experiments were conducted at Blacksburg. The results are presented in Table III.

These results show clearly that the largest total gain per acre is made from heavy grazing. However, whether to graze heavily or lightly will depend on whether the *total gain per acre* or the *gain per individual animal* is the chief consideration.

The effect of the two systems of grazing on the sod was very pronounced. In 1913 the field used for heavy grazing during the years 1913-1917 was full of weeds, while the field used for light grazing during this period was free of weeds and had a compact bluegrass and red-top sod. At the end of the experiment in 1917 the character of the sod and vegetation on the two fields was completely reversed.

From a standpoint of gain made by the animals grazed, the stock grower will have to use his own judgment whether to practice heavy or light grazing. But to improve and thicken bluegrass sod heavy grazing is far superior to light grazing.

ERADICATION OF WEEDS IN PASTURES

Weeds are among the worst enemies of bluegrass pastures in Virginia. They are not only unsightly, but occupy land where grass should be growing. Among the common weed pests of bluegrass pastures are ox-eye daisy, stick weed, hawkweed, broom sedge, plantains, and thistles. Satisfactory results have been obtained by mowing the pastures frequently during the growing season. Heavy grazing by cattle or sheep will greatly aid in eradicating weeds and thickening the sod. In those pastures which have been lightly grazed or grazed by horses, the weeds have gained, in many instances, much headway. As a rule, weeds indicate depleted soil fertility. However, much better results may be expected from the application of fertilizers to pastures before weeds become numerous than after the weeds have secured a hold. In fact, many weeds thrive just as well as the grass from the fertilizer applications, and if they are numerous at the time of application the grass will be held in check. With some weeds the application of spray material seems to give best results.

Broom Sedge

In 1909 and 1910 this station conducted some experiments to determine the effect of applications of different fertilizers in eradicating broom sedge from bluegrass pastures. Acid phosphate, nitrate of soda, and muriate of potash were applied alone, and in combination; also stable manure at the rate of 500 pounds per acre. The results of these experiments are summarized in this Station Bulletin 204, as follows:

"There was a marked decrease in the broom sedge after the first season on every plat which received either acid phosphate or nitrate of soda. The

best results were obtained when the two were used together. Bone meal and stable manure reduced the stand of broom sedge, but were not so effective as acid phosphate. The contrast between the fertilized and unfertilized plats is more marked now than it was at the close of the year that the fertilizers were applied. Not only has the broom sedge disappeared from the plats fertilized with phosphorous and nitrogen, but there has been a great improvement in the stand of bluegrass and white clover. The increase of white clover (*Trifolium repens*) is especially noticeable where acid phosphate was used."

Hawkweed

Hawkweed is a serious pest of recent introduction into the bluegrass of Southwest Virginia. From experiments carried on at Blacksburg in pastures badly infested with this pest, it was found that this weed can be eradicated by use of certain materials. A description of the plant and results of the experiment follow.

Field hawkweed is a small plant one to two feet tall, unbranched, erect, and covered with short black hairs. The stem is without leaves, except an occasional bract. The leaves of the plant, which are hairy on both sides, are clustered around the base, forming a dense mat which smothers out other plants, among which the weed is growing. The showy yellow flowers are borne in a cluster at the top of the stem. Only a few of the flowers open at one time; the remainder of the cluster consists of buds in various stages of growth. The flowering period extends from June to September. The plant is a perennial and has two methods of reproduction; namely, by seeds and by runners or stolons.

The bad reputation of field hawkweed is due to the rapidity with which it spreads and to the fact that the mat formed by the leaves is so dense as to kill other plants among which it may start. The plants spread from one field to another or from farm to farm by seed which are carried by the wind. Besides dissemination by means of seed, the plants propagate rapidly by means of runners. This latter method of reproduction is the same as that found in the strawberry. The runners take root and produce new plants. The new plants in turn send out runners and as a result other plants are crowded out in a remarkably short time. The roots are fibrous and intermingle, forming a dense mass. Large pieces of hawkweed sod can be removed intact just as can bluegrass sod. Animals dislike the plant, either in the green or dry state, because of the hairs which cover all parts of the plant and because of its bitter juices.

The Virginia Experiment Station has been conducting experiments in an attempt to find some material that would be effective in combating the hawkweed without injuring the grass permanently. Of the materials tried,

sodium arsenite, one-fifth pound to one gallon water; nitrate of soda, three pounds to one gallon water; salt solution, three pounds to one gallon water; and dry salt, 4,000 pounds per acre, have given good results. All the solutions were applied as a spray at the rate of 150 gallons per acre. Each of the solutions and the dry salt were applied at thirty-day intervals, beginning with May 1st and ending October 1st. At the time of later applications, the plats which had been previously treated were again treated when any hawkweed was present. Notes were taken while the experiment was being carried on in 1917, and again about June 1, 1918.

Sodium arsenite completely killed the hawkweed when the sprays were repeated at thirty-day intervals, beginning with May 1st and ending October 1st. The grass was slightly injured but recovered quickly. It is well to remember that sodium arsenite is a deadly poison and stock should not be pastured on grass sprayed with this material until it has been washed off by rains.

Applications of nitrate of soda solution at thirty-day intervals gave good results, but not so good as sodium arsenite. The grass was slightly injured but recovered quickly.

Dry salt was very effective in killing hawkweed; very few plants appeared after one application. At the same time all other vegetation was killed and did not appear to any great extent until the following spring. It seems that hawkweed can be effectively killed by a single application of dry salt in the late fall and the grass will appear in good condition the following spring.

Applications of salt sodium at thirty-day intervals were effective in killing hawkweed, but inferior to applications of dry salt. Salt solution injured the grass less than dry salt, but it did not recover to any great extent until the following spring.

Where it is practical to cultivate land containing hawkweed, it is easy to eradicate the pest. If the land is planted to some cultivated crop, such as corn, and kept well tilled, the hawkweed can usually be successfully destroyed in one season.

Summary

1. The practice of alternate grazing is of doubtful value and is not to be generally recommended.

2. Fertilizers containing phosphorous in a readily available form, as acid phosphate, should give profitable returns when applied to run-down or heavily grazed bluegrass pastures in Virginia.

3. From a standpoint of animal gains, the type of bluegrass farming will govern largely whether heavy or light grazing is advisable. If the main object is to improve bluegrass pastures; that is, to eradicate weeds

and thicken the sod, heavy grazing is far superior to light grazing. *It is more injurious to bluegrass pastures* to undergraze than to graze heavily.

4. The application of certain fertilizers has greatly aided in eradicating and holding broom sedge in check. The application of certain materials to pastures badly infested with field hawkweed have been very beneficial in eradicating the pest and improving the sod.

5. It is to be remembered that the results reported in this paper were secured on a limestone soil and on a bluegrass pasture.

FINISHING HEAVY STEERS ON BLUEGRASS PASTURE SUPPLEMENTED WITH VARYING AMOUNTS OF COTTONSEED MEAL

By R. E. Hunt

Under conditions prevailing in sections where heavy steers are fattened on bluegrass pasture without any supplemental feed it takes nearly the whole grazing season to obtain the desired finish, thus causing a scarcity of fat cattle on the markets of the East during July and the first half of August, when relatively high prices are being paid. The grass-fat steers begin to move about August 20th, and by September 20th to October 10th the eastern markets are fairly glutted with good fat steers and the prices usually decline.

The Virginia Agricultural Experiment Station conducted an experiment during the summer of 1916 to test the effects of feeding varying amounts of cottonseed meal to three-year-old steers being grazed on typical bluegrass pasture. The objects of this experiment were (1) to determine the advisability of supplementing grass pastures with cottonseed meal from an economical point of view, taking into consideration the cost of gains, gains per steer, finish, and selling value; (2) and to determine the best methods of handling three-year-old steers when grazing with the idea of producing export steers so that they would be sufficiently finished to take advantage of the usually high market price during July and early August.

Pasture and Grazing Season.—The pasture was a very typical bluegrass pasture; not the best but about the average pasture found in this section. The land was fairly rolling and fresh water was available at all times. The grazing season was exceptionally good, due to an abundance of rain throughout the grazing period. The amount of rainfall in the grazing season is shown in Table I.

The Animals.—The Animals used were high-grade Shorthorn steers with an average weight of 1,043 pounds. The steers were wintered on corn silage and corn stover with a very small amount of cottonseed meal and were in rather thin condition. They were turned on grass pasture April 25 and the experiment started May 19, 1916.

Weights and Weighings.—The method of weighing was to make individual weights at the beginning of the experiment, and the end of each four-week period, and at the end of the experiment. Weighings were made on only one day and at 5 or 6 o'clock in the morning.

Table I.—Data giving dates and amount of rainfall in inches during the grazing season of 1916.

Day	May	June	July	August	September	October
1				.50	.08	
2				.50	.02	
3		1.6				
4	.10			.75		
5						
6		1.6		.08		
7		.18		.85		
8		.86				
9			1.48	.10		.04
10			1.35			
11				.22		
12				.08		
13				.15		
14			.14		.42	
15		1.00	2.50	.20	.70	.10
16		.28	.50	.38		.50
17			.44			.20
18			.68			.60
19						.62
20		.40				
21						
22	1.28		.14		.45	
23	.53					
24		1.10	.10			
25		.75				
26			.36			
27			.10			
28		.10				
29	1.42				2.30	.15
30	.33					.67
31						
Total	3.81	8.07	7.79	3.63	3.97	2.88

Table II.—Data on five lots of steers, feeds, weights, cost per 100 pounds gain, and gain in weight.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
No. of steers per lot	10	10	10	10	20
Pounds of cottonseed meal fed per steer per day with pasture........	1	2	3	4	0
Average weight per steer, May 19, 1916, pounds	1053	998	1022	1038	1075
Average gain per steer, 1st four-week period, pounds	143	131	140	97	168
Average gain per steer, 2nd four-week period, pounds	40	78	76	85	57
Average gain per steer, 3rd four-week period, pounds	42	43	31	39	51
Average gain per steer, 4th four-week period, pounds	82	85	73	74	79
Average gain per steer 5th four and one-half week period, pounds	33	43	42	46	30
Average weight per steer, Oct. 10, 1916	1393	1378	1384	1379	1460
Average gain per steer, May 19—Oct. 10, pounds	340	380	362	341	385
Cost of pasture per steer 5⅛ months @ $2 per mo.	$10.25	$10.25	$10.25	$10.25	$10.25
Total amount cottonseed meal fed per steer, pounds	144	288	432	576	none
Cost of cottonseed meal fed per steer at $40 per ton	$ 2.88	$ 5.76	$ 8.64	$11.52	$ 0.00
Cost of pasture and cottonseed meal May. 19—Oct. 10	$13.13	$16.01	$18.89	$21.77	$10.25
Cost per 100 pounds gain...........	$ 3.86	$ 4.20	$ 5.22	$ 6.38	$ 2.64

Discussion

The steers were divided into five lots, practically equal as regards quality, condition and breeding. The pasture grazed by the twenty steers without cottonseed meal was adjacent to that grazed by the steers fed cottonseed meal. The forty steers fed varying amounts of cottonseed meal were marked so that the lots could be readily distinguished and the steers were divided into their respective groups, each morning at 11:30, and the cottonseed meal was then fed. After all the steers had cleaned up their feed, they were allowed to return to pasture. After the first month it was thought advisable to feed the cottonseed meal at 6:30 P. M. instead of 11:30 A. M., because the steers would graze but very little after they had been fed the meal. The amount of grass available was abundant at all times and of good quality. The steers fed the meal did not graze as much in the afternoons or evenings as those not receiving the meal, and those steers receiving four pounds of meal grazed much less than those receiving one, two or even three pounds of cottonseed meal.

As far as any one could determine without actual slaughter tests, there was apparently no difference in the finish of the different groups of steers except what would be expected from the difference in the gains during the grazing season.

Statement of Results

Virginia bluegrass pasture, during a good grazing season, produced larger gains than pasture supplemented with cottonseed meal.

Steers fed one and four pounds of cottonseed meal did not gain as much as those fed two and three pounds of cottonseed meal when used as a supplement to bluegrass pasture.

Steers fed cottonseed meal as a supplement to bluegrass pasture did not graze as much as those on pasture without the cottonseed meal.

SELF FEEDERS FOR DAIRY COWS

By R. E. HUNT[1]

Self feeders have proved very successful for feeding swine of various ages where the maximum gains are desired and where the greatest gains are desired with the minimum amount of feed in the least number of days for 100 pounds gain. The Iowa[2] and Missouri[3] experiment stations found self feeders to be a very desirable method of feeding hogs of various ages and under different conditions. Also, the Illinois[4] station found that this method of feeding was fairly well adapted to fattening beef cattle.

The self feeder having proved very satisfactory with swine and fairly satisfactory with the fattening of beef cattle, an experiment was planned to test the merits of the self feeder method of feeding dairy cows. The object of the experiment was to study the effects of feeding dairy cows by the "free-choice" system. If practical, it was determined to work out best feeds to be used and kind of self-feeder best adapted for feeding dairy cows.

Four cows with Advanced Registry records were selected, and after their usual morning feed were placed in the lot where they had access to the self feeder which was filled with the following feeds in separate compartments: Corn meal, wheat bran, cottonseed meal, peanut meal and linseed meal, with corn silage in the feed racks. The self feeding racks were built for the silage and the cows were fed all of the corn silage they would eat. The silage racks were filled once each day with an amount that would last the cows during the next 24 hours without any waste from spoiling. A self feeder for the concentrate was built very much on the plan used for

---

[1] The author wishes to acknowledge the assistance rendered by R. M. Patterson, Jr.

[2] The American Society of Animal Production, Dec., 1917, page 36.

[3] Missouri Bulletin No. 144. Agr. Exp. Station.

[4] "Beef Production" by Mumford, page 155.

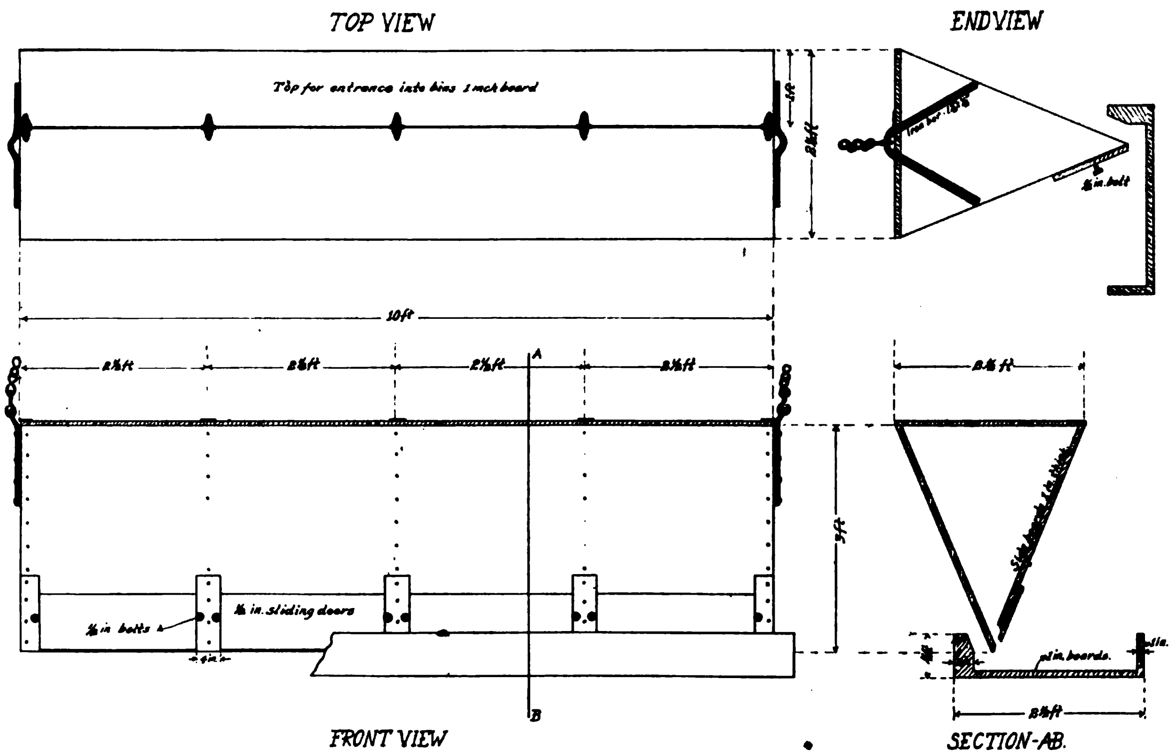


FIG. 1—Diagram showing details of the construction of the self feeder used in this experiment.

swine, only adapting the height and other dimensions suitable for the cows. This type of feeder did not prove satisfactory for such concentrates as cottonseed meal, linseed meal, and peanut meal, for they would absorb some moisture, even when the self feeder was under a good shed and well protected from the elements, causing the concentrate to form an arch above the opening where the feed should gradually feed out, making it impossible for the cows to get the feed desired. This difficulty was overcome by making a feeder as illustrated in Fig. 1.

It will be noted that the feeder is built V-shaped and about 10 feet long, being divided into five separate compartments so that each concentrate could be placed in a compartment by itself and the cows could select the feed most desired. Each compartment has a sliding door at the bottom to regulate the size of opening for the different feeds. The size of the opening varied from .5 inch to 1.5 inches, depending upon the feed. Corn meal and bran required an opening of only .5 inch, while peanut meal, cottonseed meal, and linseed meal should have openings of 1.25 to 1.5 inches. The feeder was supported by a single rod at each end, thus allowing the feeder to swing free. Under the feeder was an ordinary feed trough with a "bump board" 2.5 inches back of the bottom of the V-shaped hopper when hanging naturally. When the feed does not come down into the feed trough the cows work at the V-shaped hopper and in a short time learn that by pushing or bumping the V-shaped hopper with their heads, and knocking it back against the "bump board," the jar causes the feed to work down as it should. This does not cause the feed to come down into the feed trough too fast.

Description of cows used in experiment.—The cows used in this experiment were all Register of Merit or Advanced Registry cows with yearly records. It can be safely said that these cows were much above the average for three of them had two yearly records and the fourth cow was only a young cow in second lactation period during this experiment and later qualified for her second yearly record. These cows were in good milking condition, the two Jersey cows had averaged 23.2 and 26.5 pounds of milk for 253 and 102 days, respectively, and the two Holstein-Friesian cows had averaged 57.3 and 40.2 pounds of milk for 75 and 125 days, respectively, previous to the experiment.

The records of the individual cows while on this experiment compare very closely to the average of the four, and for that reason the individual records were not included. While it is true that only four animals were used, the results are so uniform and positive that it would be safe to assume that similar results would be obtained with other high producing dairy

cows of either the Jersey or Holstein-Friesian breed. The Jersey cows adapted themselves to the self-feeder as well as the Holstein-Friesian cows, and vice versa.

Table 1.—Data on cows used in self feeder experiment.

Name of cow	V. P. I. Narci Eminent	Petia Eminent	V. P. I. Lady Johanna DeKol	Dione DeKol
Breed	Jersey	Jersey	Holstein-Friesian	Holstein-Friesian
Herdbook Number...	237793	237792	201397	76684
Advanced Registry Number	1933	1934	33673	12932
Advanced Registry Records	Age 2y. 1m. Od. Milk 5,528 lbs. Fat 318 lbs.	2y. 3m. Od 6,050 lbs. 381 lbs.	2y. 3 m. 17d. 13,381 lbs. 504 lbs.	5y. 10m. 15d. 15,822 lbs. 578 lbs.
	Age 4y. 2m. Od. Milk 7,035 lbs Fat 413 lbs.	3y. 6m. Od. 6,052 lbs. 387 lbs.		8y. 4m. 26d. 17,992 lbs. 773 lbs.
Age at last freshening	7y. 2m. 17d.	7y. 5m. 6d.	4y 0m. 12d.	12y. 1m. 12d.
Date of last freshening	6-1-16	11-2-16	11-29-16	10-9-16
Number of days in milk previous to beginning of test, Feb. 17, 1917	253	102	75	125
Total milk production to Feb. 17, 1917	5887	2698	4297	5024
Total fat production to Feb. 17, 1917....	303.9	149.8	134.9	151.7
Average daily milk production to Feb. 17, 1917	23.2	26.5	57.3	40.2
Average daily fat production to Feb. 17, 1917	1.20	1.47	1.80	1.21
Weight of cow, Feb. 17, 1917	850	915	1360	1320
Date of breeding....	1/1/17	5/15/17	2/24/17	

Table 2.—Feeds fed, and average quantity of feeds consumed per head per day for periods of four weeks.

Periods of 4 wks. each	1	2	3	4	5
	Pounds	Pounds	Pounds	Pounds	Pounds
Corn silage	45.36	40.12	41.83*	on pasture	on pasture
Cracked corn	5.16	5.00	7.10	6.57	8.93
Wheat bran	5.15	9.64	4.52	4.50	3.60
Cottonseed meal	.464	.714	.926	1.214	2.700
Linseed meal	3.73	5.00	6.95	Discontinued	
Peanut meal	.250	.256	.300	.414	3.440
Total grain	14.75	20.61	19.80	12.70	18.67

Quality of feeds fed.—Corn silage was of good quality from field corn that would have made 35 to 40 bushels of corn per acre. The cracked corn was graded as No. 2 market corn. The concentrated feeds used had the following guaranteed analyses:

	Protein	Fat	Carbohydrates	Fiber
	Percent	Percent	Percent	Percent
Wheat bran	14.5	4.2	54.9	9.6
Cottonseed meal	38.6	6.9	22.0	12.0
Linseed meal (o. p.)	33.0	6.0	43.0	10.0
Peanut meal	45.0	8.0	28.7	5.2

The amount of corn silage is about what would ordinarily be fed to cows of this size and production under the usual method of hand feeding. The amount of concentrate is very much above what would usually be fed and much more than is recommended or called for by the different standards. These cows consumed an average of 17.3 pounds of concentrate per day and produced 25.6 pounds of milk per day, or, to put it in a different form, the cows consumed 1 pound of concentrate for every 1.47 pounds of milk produced testing 4.18 percent fat. The average weight of the cows during the test was 1,168.5 pounds.

---

*Corn silage fed during first half of period and cows turned on bluegrass pasture second half of period.

Table 3.—Digestible protein and net energy requirements for cows used in this experiment producing 25 pounds of 4 percent milk (Armsby's Standard).

	Digestible Protein	Net energy
	Pounds	Therms
Maintenance for cows weighing 1250 pounds........	.63	6.96
Nutrients required to produce 25 pounds 4% milk.	1.225	6.625
Total nutrients required for cows	1.855	13.585

Table 4.—Nutrients consumed during first four-week period.

Kind of feed used	Quantity Consumed	Digestible Protein	Net energy
	Pounds	Pounds	Therms
Silage	45.36	.499	7.212
Corn	5.16	.387	4.412
Bran	5.15	.644	2.730
Cottonseed meal	.464	.155	.418
Linseed meal	3.73	1.126	3.316
Peanut meal	.25	.106	.234
Total nutrients consumed	....	2.917	18.322
Standard required	....	1.855	13.585
Excess nutrients consumed	....	1.062	4.737

Table 5.—Nutrients consumed during second four-week period.

Kind of feed used	Quantity Consumed	Digestible Protein	Net energy
	Pounds	Pounds	Therms
Corn silage	40.12	.441	6.379
Corn	5.00	.375	4.275
Bran	9.64	1.205	5.109
Cottonseed meal	.71	.237	.639
Linseed meal	5.00	1.510	4.446
Peanut meal	2.56	1.096	2.395
Total nutrients consumed	....	4.864	23.243
Standard nutrients required	....	1.855	13.585
Excess nutrients consumed	....	3.009	9.658

Table 6.—Nutrients consumed during third four-week period.

Kind of feed used	Quantity Consumed	Digestible Protein	Net energy
	Pounds	Pounds	Therms
Corn silage*	41.83	.460	6.651
Corn	7.10	.533	6.071
Bran	4.52	.565	2.396
Cottonseed meal	.926	.309	.833
Linseed meal	6.95	2.099	6.179
Peanut meal	.30	.128	.281
Total nutrients consumed		4.094	22.411
Standard required		1.855	13.585
Excess nutrients consumed		2.239	8.826

Table 7.—Nutrients consumed during fourth four-week period in addition to good bluegrass pasture.

Kind of feed used	Quantity Consumed	Digestible Protein	Net energy
	Pounds	Pounds	Therms
Bluegrass pasture			
Corn	6.57	.493	5.634
Bran	4.50	.563	2.385
Cottonseed meal	1.214	.405	1.093
Peanut meal	.414	.177	.387
		1.638	9.499

Table 8.—Nutrients consumed during fifth four-week period in addition to good bluegrass pasture.

Kind of feed used	Quantity Consumed	Digestible Protein	Net energy
	Pounds	Pounds	Therms
Bluegrass pasture			
Corn	8.93	.670	7.635
Bran	6.36	.795	3.371
Cottonseed meal	2.70	.902	2.430
Peanut meal	3.44	1.472	3.218
		3.839	16.654

*Corn silage fed two weeks out of four.

From tables 4 to 8 it will be noted that the cows consumed feed in large quantities in excess of what was really needed for their maintenance and milk production. The first period the excess was 1.06 pounds of digestible protein and 4.7 therms. The second period the excess was 3.01 pounds of digestible protein and 9.66 therms, showing that the cows learned to eat more feed but they did not make proper use of the feed consumed from the standpoint of the dairy cow. During the third period when they were fed corn silage for two weeks and were on good bluegrass pasture the remaining two weeks the excess feed consumed was not quite as great as the previous period. In comparing the two periods where the cows had the run of good bluegrass pasture, the nutrients consumed in addition to the grass was 1.63 pounds of protein and 9.49 therms, which was undoubtedly in excess of the standard requirements. During the following period the amount of nutrients consumed in addition to the bluegrass was 3.83 pounds of digestible protein and 16.65 therms, which is in itself an excess of nutrients, showing that other conditions being uniform, the longer the cows were fed by the self feeder method the greater would be the consumption of concentrates, within certain limits.

During the experiment there was no sickness of the cows, and their general condition seemed to improve. The cows were fed their usual feed previous to the experiment which was all the corn silage that they would consume and about 1 pound of concentrate for every 4 pounds of milk produced for the Holstein-Friesian cows, and 1 pound of concentrate for every 3.25 pounds of milk produced for the Jerseys. The cows were placed in the self feeder lot immediately after their regular feed and the rack for silage and the five different hoppers were each filled with the different feeds used. On two or three occasions there were very slight indications of scours with some of the animals and it was nearly always noticed that the particular animal affected had eaten large quantities of either linseed meal or bran.

Table 9.—Average production, feed consumed, and weight of cows while on test.

Weeks	Average milk per week pounds	Average per cent fat per week	Average fat production per week, pounds	Average weight of cows, pounds	Average silage consumed per head per day, pounds	Average grain consumed per head per day, pounds
1	187.5	4.40	7.433	1100		
2	159.2	4.63	5.995	1173		
3	172.8	4.00	6.633	1156		
4	191.8	3.80	7.108	1130	45.36	14.75
5	194.0	4.38	7.425	1129		
6	177.6	4.00	6.175	1143		
7	179.6	4.25	6.800	1160		
8	176.6	4.63	7.400	1175	40.16	20.61
9	197.0	4.40	7.300	1146		
10	185.9	4.53	7.725	1139	41.83	19.80
11	171.6	4.05	7.425	1138		
12	178.3	3.95	6.850	1175	Grass	
13	182.9	3.80	6.650	1200		
14	183.8	4.30	7.475	1210		
15	191.7	4.13	7.275	1208		
16	170.6	4.40	6.550	1210	Grass	12.70
17	174.4	4.08	6.425	1203		
18	160.1	4.13	6.250	1199		
19	181.8	4.05	6.575	1196		
20	162.0	3.70	5.075	1180	Grass	18.67

The average production of milk per cow per week was fairly uniform and for the twenty weeks the decrease was about the natural decrease caused by advancing lactation. From Fig 2 it will be noted that the milk production, fat production, percent fat, and weight of the cows decreased faster during the last period than at any other. The only explanation that seems plausible is that of excessive high temperatures during the last week in June or during the 19th week of the test. Maximum temperatures ran as high as 94 degrees Farenheit, which is very high for June temperatures. Milk production is a dairy cow's work, which is very trying on the animal because it is work 24 hours of the day and 7 days in the week. The cows increased some in weight while being fed on the self feeder, due to the large amount of concentrate consumed.

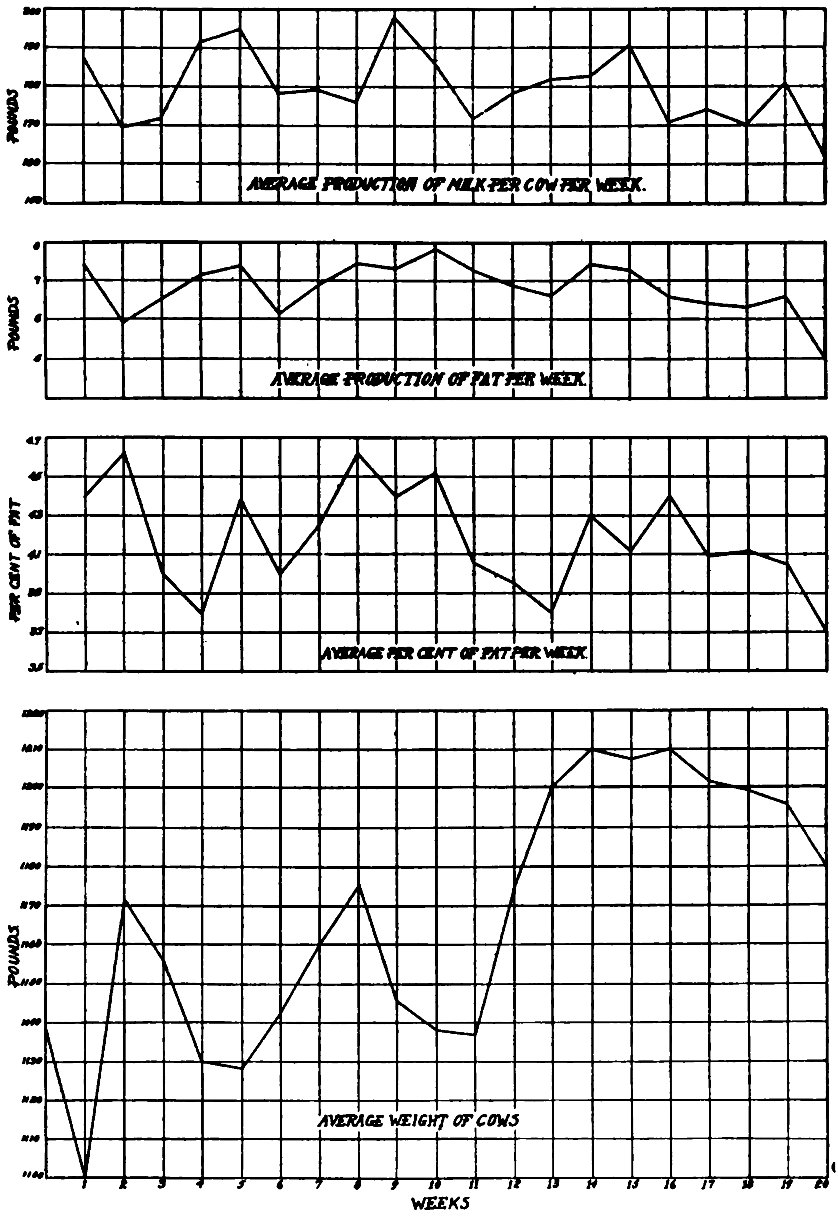


FIG. 2—Chart showing average weekly milk and fat production, percent of fat and weight of cows.

Statement of Results

From the above data the following statements can be made:

The "Free Choice" method of feeding proved *very uneconomical*.

No difficulty was experienced with the cows gorging themselves or becoming foundered when placed on the self feeder when they were properly fed, previous to the "Free Choice" method of feeding.

The self feeder must be properly built and regulated before it will give satisfactory results.

The "Free Choice" method is an excellent method to compare the palatability of different feeds and may be used for that purpose.

Other conditions being uniform, the longer that the cows were fed by the self feeder method the greater was the consumption of concentrates within certain limits.

METEOROLOGICAL RECORDS FOR THE YEARS 1917 AND 1918

By H. L. PRICE, *Observer*

Reading of Maximum and Minimum Thermometers, 1917.

Date	January		February		March		April		May		June	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	49	18	51	25	38	34	75	40	65	48	84	49
2	52	32	11	0	38	30	70	50	64	47	85	56
3	59	32	19	–4	39	29	57	38	67	46	77	47
4	51	33	41	1	36	32	56	37	56	45	76	45
5	57	43	5	–4	28	20	52	35	52	43	82	49
6	47	29	29	3	45	17	37	32	50	37	85	50
7	53	25	44	17	54	22	53	30	46	40	76	42
8	52	30	44	32	51	40	44	30	45	39	74	51
9	54	34	30	9	51	33	41	32	54	44	75	48
10	54	33	29	6	49	23	55	28	59	36	74	49
11	37	12	29	18	68	44	74	35	59	41	78	53
12	27	9	21	6	63	52	73	38	50	39	86	53
13	30	21	42	3	37	32	55	35	50	39	87	55
14	41	19	44	25	56	33	54	28	58	34	75	53
15	22	19	47	33	55	34	57	32	69	39	64	45
16	35	22	39	29	44	37	67	33	67	45	63	42
17	38	26	57	29	57	30	79	44	78	44	76	34
18	47	33	56	37	30	23	80	48	81	43	82	39
19	37	24	43	31	41	20	84	48	85	48	81	43
20	42	22	57	35	60	30	84	58	85	49	80	46
21	37	30	53	26	60	40	71	57	86	48	76	49
22	59	33	55	28	57	33	73	48	75	49	82	58
23	37	22	47	26	52	43	78	45	60	44	88	57
24	41	26	54	38	55	40	79	50	60	41	86	46
25	38	26	55	27	58	30	54	47	69	42	88	53
26	42	22	67	36	60	32	70	48	70	37	89	55
27	49	25	64	48	49	36	74	48	80	38	94	58
28	57	35	52	34	50	30	70	48	76	40	92	55
29	61	36			56	38	56	46	66	41	86	55
30	61	38			59	33	80	50	75	39	82	48
31	64	38			75	34			72	41		
Average	46.1	27.3	42.3	21.1	50.6	32.3	65.	41.2	65.3	42.1	80.7	49.2

Reading of Maximum and Minimum Thermometers, 1917—Continued.

Date	July		August		Sept'ber		October		Nov'ber		Dec'ber	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	72	58	93	65	82	62	59	41	45	21	43	38
2	90	58	90	62	83	61	68	28	40	18	53	33
3	81	58	87	63	82	56	75	32	39	20	59	36
4	81	55	82	61	84	55	76	41	61	25	53	40
5	86	50	85	56	81	56	74	44	61	19	43	25
6	83	53	87	59	85	55	56	41	64	24	39	23
7	77	56	78	52	80	58	66	25	65	43	36	21
8	86	56	84	51	80	53	68	34	63	23	38	26
9	86	54	84	63	81	57	49	33	66	25	33	0
10	85	52	77	56	81	51	56	23	63	28	20	-1
11	78	55	82	58	77	40	60	27	63	27	20	-1
12	82	55	85	61	70	33	53	39	63	33	27	1
13	82	56	82	44	73	33	55	31	61	44	20	-11
14	86	55	84	52	71	50	68	23	63	40	25	7
15	78	55	86	40	87	58	74	25	54	30	26	5
16	81	61	87	51	76	56	78	41	50	35	25	12
17	75	51	82	45	71	43	77	43	59	31	33	0
18	72	52	83	36	82	39	72	41	64	26	35	18
19	76	49	80	38	76	39	68	46	55	41	39	5
20	74	49	83	42	71	42	52	30	55	29	50	10
21	80	52	80	42	79	49	54	22	58	38	50	17
22	80	56	84	44	78	43	58	25	51	37	43	32
23	76	65	81	55	79	49	60	33	45	27	39	15
24	80	55	80	49	78	47	56	22	30	19	48	28
25	86	56	80	41	77	38	52	32	34	17	42	28
26	84	54	79	35	66	51	58	27	37	24	36	12
27	82	56	81	39	61	41	67	33	35	20	27	-7
28	86	58	87	40	66	56	65	41	45	33	32	5
29	88	53	83	51	75	59	68	39	45	33	33	5
30	90	59	84	51	66	51	62	27	40	33	13	-27
31	91	64	83	61			45	20			17	-8
Average	81.7	55.4	83.3	50.4	76.6	49.3	62.7	32.5	52.4	28.7	35.4	12.5

Reading of Maximum and Minimum Thermometers, 1918.

Date	January		February		March		April		May		June	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	17	8	36	18	71	46	70	40	53	40	90	63
2	17	10	32	25	62	26	72	40	66	32	88	62
3	21	−7	42	27	59	38	69	48	72	39	78	64
4	24	2	40	12	56	30	63	46	78	45	80	54
5	39	−3	23	1	70	44	53	25	79	46	82	52
6	37	18	44	8	60	42	55	30	82	40	78	60
7	33	23	45	32	55	36	58	25	72	48	75	48
8	25	17	43	25	55	26	51	44	71	55	74	46
9	25	6	42	32	55	34	50	32	72	44	82	46
10	29	14	50	35	50	31	37	25	82	54	83	51
11	29	11	50	30	56	20	37	32	81	46	83	51
12	34	5	58	27	50	30	38	29	87	50	83	59
13	17	−5	58	37	67	45	42	30	73	55	79	50
14	34	4	51	32	67	53	61	25	72	51	79	45
15	37.	21	56	78	63	35	69	30	71	46	83	52
16	36	6	49	29	52	20	65	40	61	54	87	47
17	33	21	43	27	55	32	70	46	73	56	81	61
18	31	22	37	17	67	35	70	53	76	47	80	65
19	23	4	59	33	70	35	68	51	75	50	69	59
20	31	13	57	31	65	35	51	42	78	50	69	57
21	28	−16	32	18	60	45	70	42	78	58	63	53
22	28	11	34	22	70	55	68	48	83	65	69	55
23	25	15	52	23	63	46	70	48	81	59	70	45
24	37	10	60	20	57	37	73	55	71	60	78	42
25	42	25	66	42	52	36	65	43	83	57	68	55
26	45	25	61	29	48	36	60	38	86	59	70	58
27	56	33	58	22	57	47	60	39	85	58	75	58
28	37	23	79	31	55	37	62	46	86	59	82	55
29	47	30			56	30	74	34	88	57	84	61
30	32	25			67	27	63	49	86	60	79	63
31	45	20			69	32			89	61		
Average	32.0	12.6	48.4	27.2	59.9	36.1	60.4	39.1	77.0	51.0	78.0	54.5

Reading of Maximum and Minimum Thermometers, 1918—Continued.

Date	July		August		Sept 'ber		October		Nov 'ber		Dec 'ber	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	78	59	74	61	78	50	72	43	55	36	40	29
2	75	55	79	59	76	48	80	43	50	31	50	22
3	81	45	83	59	75	52	76	35	59	23	50	27
4	85	58	87	60	81	52	72	40	61	29	39	29
5	87	55	92	65	79	51	80	44	61	36	51	28
6	82	60	96	70	66	51	80	55	60	25	58	38
7	82	57	95	67	65	49	74	40	66	25	52	25
8	74	60	92	65	60	50	64	32	69	29	59	30
9	72	45	87	65	72	45	70	29	65	42	58	52
10	72	42	85	65	76	43	75	35	56	38	61	40
11	75	49	89	63	73	45	77	37	56	23	42	33
12	66	48	90	65	75	53	70	48	47	20	48	35
13	72	53	91	63	69	49	76	53	54	20	53	38
14	79	47	87	65	73	43	72	39	57	40	60	42
15	83	48	84	65	78	41	66	29	63	25	57	45
16	84	55	83	63	81	53	81	33	56	34	48	35
17	79	62	82	63	75	57	82	37	70	51	53	30
18	77	57	76	63	71	58	72	45	64	40	50	25
19	72	60	67	65	79	45	63	43	45	38	47	22
20	81	57	73	41	77	45	57	44	44	37	42	37
21	82	55	80	43	53	38	65	51	42	35	43	35
22	81	58	85	50	61	30	63	30	41	30	45	36
23	85	62	87	58	67	31	64	29	38	31	59	36
24	87	64	86	60	70	31	66	37	42	20	52	40
25	81	61	82	58	74	39	61	56	41	26	42	29
26	80	63	86	57	71	39	62	56	46	24	26	23
27	82	59	80	62	67	34	68	58	60	27	35	17
28	74	63	79	62	70	36	68	59	47	35	32	24
29	81	61	82	60	72	42	65	59	52	40	28	19
30	77	65	84	60	74	40	70	53	46	32	49	15
31	75	62	80	62			61	44			41	27
Average	78.7	56.3	83.9	60.8	71.9	44.7	70.0	43.0	53.8	31.4	47.0	31.0

Table Showing Meteorological Data, January 1, 1917, to December 31, 1917.

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temp.	Lowest Temp.	Monthly Range	Precipitation in inches	Snow in inches	Prevailing Winds	Number of clear days	Number of partly cloudy days	Number of cloudy days
January	36.5	46.1	27.3	18.8	64	9	55	4.09	Trace	West	8	7	16
February	31.7	42.3	21.1	21.2	67	–4	71	3.14	4	N.W.	9	7	12
March	41.5	50.6	32.3	18.2	75	17	58	6.62	1.5	W.	13	7	11
April	53.1	65.0	41.2	24.4	84	28	56	3.54	Trace	W.	12	2	16
May	53.7	65.3	42.1	22.8	86	34	52	3.58	0	W.	23	6	2
June	64.9	80.7	49.4	30.2	94	34	60	1.34	0	W.	17	13	0
July	68.5	81.7	55.4	71.3	91	49	42	5.69	0	W.	16	14	1
August	66.9	83.3	50.4	32.9	93	35	58	1.16	0	W.	21	10	0
September	62.8	76.6	49.3	26.6	85	33	52	2.36	0	W.	20	10	0
October	42.5	62.7	32.5	30.3	78	20	58	3.59	1	W.	16	8	7
November	40.4	52.4	28.7	23.5	66	17	49	0.62	0.4	N.W.	10	7	13
December	24.0	35.4	12.5	25.0	59	–27	86	3.17	21	N.W.	8	9	14

Table Showing Meteorological Data, January 1, 1918, to December 31, 1918.

January	23.0	32.0	12.6	19.3	56	–16	78	7.11	37	West	4	9	18
February	37.4	48.4	27.2	51.1	79	1	78	1.28	1	N.W.	12	10	6
March	48.1	59.9	36.1	36.9	70	20	50	3.66	0	N.W.	16	4	11
April	54.6	60.4	39.1	21.1	74	25	49	6.28	3.2	West	4	14	12
May	64.0	77.0	51.3	25.2	89	32	57	3.90	0	"	14	8	9
June	53.0	78.0	54.5	35.4	90	42	48	9.71	0	"	11	4	15
July	66.5	78.7	56.3	23.0	87	42	45	8.26	0	"	8	8	15
August	70.0	83.9	60.8	22.5	96	41	55	8.00	0	"	10	6	15
September	57.0	71.9	44.7	27.2	81	30	51	2.90	0	"	14	4	12
October	56.0	70.0	43.0	27.4	82	29	53	5.95	0	"	14	4	13
November	42.0	53.8	31.4	21.9	70	20	50	2.07	0	"	16	4	10
December	39.0	47.0	31.0	16.4	59	15	44	5.94	0	"	4	4	23

ANNUAL REPORT

OF THE

VIRGINIA POLYTECHNIC INSTITUTE

Agricultural Experiment Station

1918 - 1919

CONTENTS

The more popular and immediately applicable results of the work of this Experiment Station are presented in Bulletins and Technical Bulletins, which are for general distribution. This Report contains a brief statement of the work in progress and several Articles which are not published elsewhere.

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

1918-1919

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

LYNCHBURG, VA.
BROWN-MORRISON CO., INC., PRINTERS
1920

ORGANIZATION

OF THE

VIRGINIA AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

The Executive Committee of the Board of Visitors of the Virginia Polytechnic Institute.

JOHN THOMPSON BROWN, *Chairman*	R. F. D., Evington, Bedford County
J. B. WATKINS	Midlothian, Chesterfield County
J. A. TURNER	Hollins, Roanoke County
W. C. SHACKLEFORD	Proffit, Albemarle County
J. A. BURRUSS, *ex officio*	Blacksburg, Montgomery County

STATION STAFF

J. A. BURRUSS, A. M.	President
A. W. DRINKARD, JR. Ph. D.	Director
H. L. PRICE, M. S.	Horticulturist
W. B. ELLETT, Ph. D.	Chemist
†W. J. SCHOENE, M. S.	Entomologist
T. B. HUTCHESON, M. S.	Agronomist
F. D. FROMME, Ph. D.	Plant Pathologist and Bacteriologist
G. S. RALSTON, M. S.	Field Horticulturist
R. E. HUNT, M. S.	Animal Husbandman
C. W. HOLDAWAY, M. S.	Dairy Husbandman
H. H. HILL, M. S.	Associate Chemist
T. K. WOLFE, M. S.	Associate Agronomist
W. G. HARRIS, M. S.	Associate Chemist
A. B. MASSEY, B. S.	Associate Plant Pathologist and Bacteriologist
J. C. HART, B. S.	Associate Agronomist
S. A. WINGARD, M. S.	Assistant Plant Pathologist
†C. B. NICKELS, M. Sc.	Assistant Entomologist
†L. A. STEARNS, M. Sc.	Assistant Entomologist
†G. W. UNDERHILL, M. Sc.	Assistant Entomologist
C. F. WARREN, B. S.	Assistant Horticulturist
F. S. GLASSETT	Assistant Agronomist
R. C. THOMAS, M. S.	Assistant Plant Pathologist
M. E. GARDNER, B. S.	Assistant Horticulturist
C. I. WADE	Treasurer
J. B. FOGLEMAN	Executive Clerk

COUNTY EXPERIMENT STATIONS

T. B. HUTCHESON, M. S.	Supervisor County Experiment Stations
W. W. GREEN (Bowling Green)	Supervisor Tobacco Investigations, and Superintendent Bowling Green Station
B. G. ANDERSON, B. S. (Appomattox)	Superintendent Appomattox Station
R. P. COCKE (Lightfoot)	Superintendent Lightfoot Station
*E. R. HODGSON, M. S. (Staunton)	Superintendent Staunton Station
D. J. BERGER (Chatham)	Superintendent Chatham Station
*A. N. HODGSON, M. S. (Martinsville)	Superintendent Martinsville Station
*M. O. WILSON (Charlotte C. H.)	Superintendent Charlotte Station
E. T. BATTEN, B. S. (Holland)	Superintendent Holland Station

*In co-operation with the State Board of Agriculture. †State Crop Pest Commission.

Bulletins and reports are mailed free to all residents of the State who apply for them.

LETTER OF TRANSMITTAL

To His Excellency, Governor Westmoreland Davis:

SIR: In accordance with the Federal laws, approved March 2, 1887, and March 20, 1906, I transmit for your consideration the report of the Virginia Agricultural Experiment Station for the fiscal year ending June 30, 1919. It includes a brief statement of the work completed or in progress, and the principal changes which have occurred since the issuance of the last report.

Respectfully submitted,

A. W. DRINKARD, JR., *Director*.

January 31, 1920.

ANNUAL REPORT

OF THE

Virginia Agricultural Experiment Station

1918-1919

By A. W. Drinkard, Jr., *Director*

President Julian A. Burruss,
Virginia Polytechnic Institute.

Sir: I submit herewith the annual report of the Virginia Agricultural Experiment Station for the fiscal year July 1, 1918, to June 30, 1919.

The work of the Station progressed steadily during the year. The unusual economic conditions are being felt more keenly than at any previous time. The increased cost of labor and all other service and supplies entering into the operation of the Station has brought about a corresponding curtailment of the amount of work that can be undertaken with the means available for experimental work. The plan has been to direct the Station's activities in a manner calculated to promote in the largest way possible the agricultural interests of Virginia.

PUBLICATIONS

The publications issued during the year are briefly described as follows:

Bulletin 220—Bean Rust. By F. D. Fromme and S. A. Wingard, 18 pages, 5 plates. November, 1918.

Bulletin 221—Fertilizers and their Relation to Crop Production in Virginia. By T. B. Hutcheson and T. K. Wolfe. 74 pages, 14 figures. March, 1919.

Technical Bulletin 19—A comparison of Methods for Determining Soil Acidity and a Study of the Effects of Green Manures on Soil Acidity. By H. H. Hill. 25 pages. April, 1919.

The annual report for the fiscal year ending June 30, 1918, a pamphlet of 65 pages, was issued in February, 1919, and in addition to a sketch of the progress and results of the experiments, it contained the following papers not published elsewhere:

Eradication of Field Hawkweed. By T. B. Hutcheson and T. K. Wolfe.

The Fertilization and Management of Bluegrass Pastures. By T. B. Hutcheson and T. K. Wolfe.

Finishing Heavy Steers on Bluegrass Pasture Supplemented with Varying Amounts of Cottonseed Meal. By R. E. Hunt.

Self Feeders for Dairy Cows. By R. E. Hunt.

Meteorological Records for the years 1917 and 1918. By H. L. Price.

The following papers were contributed by members of the Station Staff to scientific journals:

"Relation between Yield and Ear Characters in Corn." By T. B. Hutcheson and T. K. Wolfe. Journal of the American Society of Agronomy **10**: *pp.* 250-255. 1918.

"Angular Leafspot of Tobacco, an Undescribed Bacterial Disease." By F. D. Fromme and T. J. Murray. Journal of Agricultural Research **16**: *pp.* 219-233. 1919.

FINANCES

Table 1 sets forth briefly the fiscal transactions of the Station during the year. The Station received from the Federal Government $15,000 under the Hatch Act and $15,000 under the Adams Act. The Supplemental Fund includes income from the sale of farm crops, orchard fruits, livestock and milk in connection with the experiments supported by federal appropriations, and the expenditure of this fund is governed by the same rulings to which the federal Hatch and Adams funds are subjected. The State Fund includes the appropriation made by the State Legislature for county experiment stations and for the support of investigations and experiments at the main Station; and revenue derived from the sale of farm crops and livestock in connection with these experiments is placed in the State Fund. The State Board of Agriculture allotted $7,500 for the support of three County Stations located respectively at Staunton, Martinsville and Charlotte Court House; income from the sale of products at these three Stations is placed in the State Board of Agriculture Fund and is used for the same purpose as the allotted fund.

Table 1.—Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1918-1919.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS					
Appropriations	$15,000.00	$15,000.00		$30,000.00	$ 8,250.00
Balances from previous year			$ 4,724.19	6,844.47	375.74
Farm products, etc.			4,313.58	3,319.80	2,220.20
	$15,000.00	$15,000.00	$ 9,037.77	$40,164.27	$10,845.94
DISBURSEMENTS					
Salaries	$ 9,273.15	$ 9,980.00	$ 90.00	$12,796.64	$ 4,441.52
Labor	2,820.35	2,809.64	365.81	3,990.65	1,875.57
Publications	383.08		750.00	1,437.20	
Postage and Stationery	345.61	3.23	9.28	286.10	76.51
Freight and express	127.84	26.04	45.87	237.65	98.42
Heat, light, water and power	85.82	9.90	6.80		3.00
Chemicals and laboratory supplies	72.95	238.30	2.16	1.25	
Seeds, plants and sundry supplies	516.04	255.20	683.06	793.36	519.84
Fertilizers	306.13	456.06		1,512.65	535.32
Feeding stuffs	74.00	726.75	614.50	1,712.39	143.20
Library	176.98		11.35	3.50	
Tools, machinery and appliances	340.52	27.64	69.12	563.01	481.07
Furniture and fixtures	126.00	9.10	75.00		
Scientific apparatus and specimens		84.15		16.15	
Livestock	3.00		14.25	5,502.65	416.50
Traveling expenses	231.46	220.09	324.14	2,331.32	394.84
Contingent expenses	40.00		5.00	5.00	
Buildings and land	77.07	153.90	447.32	1,744.33	1,458.15
Balances			5,524.11	7,230.42	402.00
	$15,000.00	$15,000 00	$ 9,037.77	$40,164.27	$10,845.94

CHANGES IN THE STAFF

S. C. Harmon, Assistant Agronomist, resigned, October 1, 1918, and F. S. Glassett was appointed in his place. E. T. Batten resumed his duties at the Holland Station on December 1, 1918, after serving six months in the Army. W. G. Harris, Associate Chemist, resumed his duties January 1, 1919, after serving one year in the Army. J. M. Trimble, Superintendent of the Staunton Station, resigned, February 1, 1919, and R. H. Cook was appointed in his place. C. F. Warren was appointed Assistant Horticulturist, January 1, 1919.

PROGRESS AND RESULTS OF EXPERIMENTAL WORK UNDER EACH PROJECT

The progress and results of experimental work under each project are briefly outlined under the several Station departments in the pages which follow. The statements are summaries of the reports made by the department heads to the director.

Horticultural Department

Effects of soil environment on fruit-bud formation (Adams Fund).—The plan of this experiment is stated in the report for 1916-1917, pp. 11 to 16. The cultural treatments have been given and fertilizer applications have been made according to the original plan. Records have been made on bloom, fruit production and tree growth. After nine years, it appears that cultural treatments are more effective in promoting fruitfulness and tree growth than fertilizer applications. The cultivated apple and peach trees are larger, much more vigorous, bloom heavier and produce more fruit than the uncultivated trees. It is to be expected that fertilizer applications will show more noticeable results when the trees reach the age for full bearing. On young apple trees nitrogenous fertilizers stimulated vegetative growth; but phosphorus and potash do not produce apparent results.

Breeding late blooming apples (Adams Fund).—No progress was made on this project during the year owing to the fact that frost at the time of blooming killed the flowers that were to be used in the breeding work. A number of hybrid seedling apple trees of known parentage are now being grown, but these have not fruited.

Commercial value of dwarf apple trees (Hatch Fund).—This experiment has been under way since 1907, and the results secured are set forth

in the annual report for 1916-1917, pp. 16-18. Observations on the behavior of varieties grown on dwarf stocks were continued during the year, and these later observations confirm the former conclusions that dwarf apple trees have very limited usefulness in this State.

Variety Studies (Hatch Fund).—This project includes a study of the behavior, at Blacksburg and at other places in the State, of tree fruits, bush fruits and grapes. The object is to accumulate reliable data for the guidance of fruit growers. This work has been in progress since the founding of the Station and it has contributed substantially to the upbuilding of the fruit industry in Virginia.

Soil management and fertilizer experiments in commercial apple orchards (State Fund).—Experiments along this line have been carried out in co-operation with fruit growers at several places in the State. The object of the work is to ascertain the relations between cultural methods and fertilizer requirements in commercial orchards on the different soil types in the fruit growing sections of the State. In the same connection studies are being made of the cover crops best suited for the improvement of the fertility of orchard soils. Fertilizer applications are made early in April as a rule. Cultivation of the soil is begun in early spring and continued to the middle or end of June. Up to the present time, tillage has been more effective than fertilizers in promoting tree growth and fruitfulness. Results from the use of fertilizers are contradictory. Nitrogenous fertilizers have usually given profitable returns; and in some cases a combination of nitrogen and phosphorus has been profitable. As a general rule, phosphates and potash have not been effective in increasing fruitfulness of the orchards.

Effects of time of pruning apple trees in different stages of vigor (State Fund).—The plan of this experiment is set forth in the annual report for 1917-1918, pp. 9 and 10. The work was carried forward this year without interruption.

Effect of time of application and sources of nitrogenous fertilizers on tree growth and fruit production (State Fund).—The application of commercial nitrogenous fertilizers to apple orchards has become quite general on many soil types in the fruit growing districts of Virginia. Nitrate of soda and dried blood are the materials generally used to supply nitrogen for this purpose. The usual practice is to apply such fertilizers in the spring soon after the petals fall from the flowers. Apparently when applied at this time it does not increase the set of fruit the current season, although it is a benefit to the fruit which does set and stimulates tree growth. The

object of this experiment is to determine the best time for applying nitrogenous fertilizers to apple trees, and to compare nitrate of soda and dried blood as sources of nitrogen for fertilizing the orchard.

Chemical Department

Fixation of phosphoric acid in soils (Adams Fund).—The work was continued along the same lines discussed in previous reports. Samples of soil were analyzed from the twenty-six plats which have been in corn continuously since 1907, the plats receiving during this time applications of phosphoric acid in different forms and amounts. The analyses of the soil and yield of corn on the plats indicate that the corn plants are able to utilize the phosphoric acid from acid phosphate, basic slag and floats equally.

The effect of the continuous application of lime to plat 18 was mentioned in our Technical Bulletin 13. From experiments conducted at other Stations it has been assumed that caustic lime burns out the organic matter, thereby reducing the store of soil nitrogen. A check plat and a limed plat in this series of field plats supplies some interesting information on this point, and the results are set forth in an article by Dr. W. B. Ellett which forms a part of this report.

The effect of green manuring on soils (Adams Fund).—This project is carried on co-operatively by the chemical department and the agronomy department. The principal work under this project consists of two groups of field experiments.

The first group of field experiments was begun in 1914, but crop yields are available beginning with the year 1912. Data are available on nitrate accumulation, nitrogen fixation, ammonification of organic nitrogenous substances, total carbon changes and lime requirements under a green manure treatment. The experimental results on lime requirements under green manure treatment were published in Technical Bulletin 19. These results show that the general belief among farmers that decomposing organic matter produces acid conditions in the soil and that this acid condition is injurious to the growth of crops is not warranted. These results showed also that the general tendency of green manure treatment is to create an alkaline condition of the soil rather than an acid condition, provided proper consideration is given to fertilizer treatment and an occasional application of lime is given in rotation. It has been pointed out by many investigators that new ground, on which oak leaves have decomposed, does not require lime and for this reason the agricultural pioneers of this State failed to recognize the need for lime until the continual drain of bases by growing crops depleted the store of lime in the soil, and then the need of lime became evident.

The experiments with green manures have demonstrated that in planning a rotation which contains a legume crop, precautions should be taken with reference to the fertilizer treatment of the soil. A place for lime should always be made. If this plan is followed there is no danger of an injurious acid condition resulting from the turning under of a green manure crop.

Experimental work on the second group of field experiments has been in progress since the fall of 1915. Four one-half acre plats were selected for this work, each plat being sub-divided into five parts containing each one-eleventh acre. In September, 1915, the plats were seeded to rye, winter oats, crimson clover and winter vetch. The green crops were cut two weeks apart, one-half of each plat being cut for hay and the other half being turned under. The plats now have received two green manure treatments, two crops of millet and two crops of wheat. Acidity determinations have been made on all plats after each green manure treatment, and so far no injurious effects in respect to soil acidity have been noted. Studies are being made on the chemical composition of the green manure crops at different stages of development, and interesting data are being accumulated on this point.

Composting raw rock phosphate and sulphur (Hatch Fund).—This experiment is being conducted along lines suggested by the Agricultural Committee of the Council of National Defense. The analysis of samples of the floats and manure compost do not indicate that the manure has increased the availability of the phosphoric acid in the floats. The soil, floats and sulphur compost resulted in a slow oxidation of sulphur with the formation of sulphate; and the availability of phosphoric acid in this compost was increased from 0.3 percent to 2.85 percent. The compost of soil, floats, sulphur and manure showed 3.27 percent of available phosphoric acid. The results do not indicate that this method is practicable from the standpoint of the farmer.

Agronomy Department

A study of some principles governing growth and maturity of corn (Adams Fund).—During the past year the effects of root pruning and detasseling have been studied in the field. Data have been assembled to study the correlation between maturity and various somatic characters. The variation in time of maturity of different plants in the same variety was studied in the field. The effect of inorganic salts on maturity was studied under control conditions in the greenhouse. Progress is being made on this project.

Cereal investigations (Hatch Fund).—This work consists of variety tests and selection work with corn, wheat, oats, rye and barley and is being continued along the lines described in the last report (pp. 13 and 14). A new experiment added to this project in 1917 dealing with rates of seeding winter oats indicates that yields may be increased by seeding three to four bushels of oats to the acre, although the prevailing practice is to sow two bushels to the acre.

Silver King corn continues to give good results when grown at the higher elevations in the State where the growing season is short. The acreage of this variety seeded last spring in the mountainous section of Virginia was more than double the acreage of any previous year since its introduction in 1916. Farmers who have grown the variety are favorably impressed by its utility under conditions where early maturity is required.

Boone County White, Casey's Pure Bred, Johnson County White, Collier's Excelsior, Virginia White Dent, Leaming, Reid's Yellow Dent and Gold Standard continue to yield well in the variety tests and are satisfactory varieties to use where the growing season is no less than 140 days There seems to be very little difference between these varieties as far as yield is concerned.

Wheat selections Nos. 112 and 131 continue to lead all other varieties in yield, and winter oat selection No. 1 gives better results than any other variety of oats tried at the Station. In the rye variety tests Giant Winter shows up well in yield of grain and Abruzzi is the most promising variety for winter pastures. Abruzzi rye also gives good yield of grain except where the winters are very severe. Spring barleys have not proved suitable for this section and will not be tested further. Of the winter barleys, Union and Tennessee Winter have given best results.

Pasture clipping experiments (Hatch Fund).—The purpose of this experiment is to determine the effects of commercial fertilizers on the growth of pasture grasses and the composition of these grasses. At intervals the grass is clipped, its weight determined and then a chemical analysis of the grass is made. This work has been in progress several years.

Forage investigations (Hatch Fund).—Cowpeas and velvet beans have not proved satisfactory for the high altitude of Southwest Virginia, and the sorghums have not given satisfactory results at this Station. Soy beans made an excellent forage crop and Hollybrook is the leading variety of soy beans in our tests considering both yield of hay and grain. Wilson and Haberlandt soy beans are proving very satisfactory early varieties for hog pasture. Medium Black and Early Green soy beans are not satisfactory varieties for hay because of their habit of shattering.

Fertilizer tests (Hatch Fund).—Experiments were begun in the fall of 1917 to determine the best place in a rotation of corn, wheat and grass to apply manure, lime and acid phosphate. These experiments are also designed to test the relative efficiency of manure, lime and phosphates when applied in small quantities often and in larger quantities at longer intervals.

Ensilage experiments (Hatch Fund).—This work was completed during the year.

Potato studies (Hatch Fund).—This work consists of a variety study of potatoes, and also an experiment on fertilizers for potatoes.

Alfalfa experiments (Hatch Fund).—Our experience has shown alfalfa to be a very uncertain crop at Blacksburg. Alfalfa requires a soil abundantly supplied with organic matter, lime and phosphorus. Unless these conditions obtain, it is impossible to secure a satisfactory stand. The best date for seeding is August 1, and the best rate is twenty pounds of seed to the acre.

Rotation and fertilizer experiments (Hatch Fund).—Phosphorus continues to give more economical results in a rotation of corn, wheat and grass than any other single fertilizer element, or any combination of elements used. The preliminary soil tests have been completed and the experiment to test the relative value of acid phosphate and raw rock phosphate when applied on an equal cost basis is now under way.

Lime tests (Hatch Fund).—Work is being continued to determine the best form of lime for agricultural purposes. These tests do not show any material difference in yields of crops obtained after using burnt lime, ground limestone or marl, when these materials are used at rates giving the same calcium oxide equivalent. A series of concrete rims were installed for the purpose of studying the question of the relation of the fineness of ground limestone to its agricultural utility.

Effects of fertilizers on the germination of seed (Hatch Fund).—During the year some tests were made to ascertain the effects of various salts used in commercial fertilizers on the germination of common field crop seed. A brief paper on this project by Mr. T. K. Wolfe forms a part of this report.

The County Experiment Stations (State Funds)

There are eight county stations, three of which are financed by the State Board of Agriculture, located at Staunton, Charlotte Court House and Martinsville; and five are financed from State appropriations, and are located at Holland, Bowling Green, Lightfoot, Appomattox and Chatham.

The chief reasons which led to the adoption of the policy of establishing county experiment stations were first, the comparative inaccessibility to many farmers, of the main station at Blacksburg; and secondly, the great differences in soil types and climatic conditions in the several regions of the State, which make it impossible to do experimental work on all crops at the same place. Annual field days are held at the county stations when large numbers of farmers assemble to avail themselves of the opportunity to become acquainted with the experiments and to hear lectures on timely agricultural subjects.

Chatham, Pittsylvania County.—The work at this station deals with the problems of farmers who are growing bright tobacco. The fertilizer tests, begun in 1908, are being continued with the view of studying the effects of nitrogen, potash and phosphoric acid singly and in combinations, on the growth of bright tobacco and other crops commonly grown in rotation or connection with bright tobacco. Particular study is being made on the sources of ammonia for bright tobacco, also the use of lime in growing bright tobacco.

Variety studies are being made with corn, wheat, rye, oats (fall and spring seeding), potatoes (early and late planting), cow peas and soy beans.

Crop rotations have been in progress many years with satisfactory results. The yield of corn with an application of 500 pounds of 16 percent acid phosphate was 57.2 bushels per acre. The yield of tobacco in this rotation in 1918 was 1,388 pounds per acre, which sold for $607.54. The most satisfactory rotation for fine bright tobacco consists of tobacco, wheat and herd's grass.

The demonstration acre of alfalfa has not given satisfactory results. A top dressing of 16 percent acid phosphate at the rate of 600 pounds per acre in the spring of 1919 greatly improved the alfalfa.

New experiments begun in 1919 include a new set of fertilizer plats, 16 in number and 1/20 acre in size, handled in a three-year rotation of bright tobacco, wheat and herd's grass. The object of this work is to determine the best proportions for combining nitrogen, potash and phosphoric acid. The plan is to begin with equal percentages of each element, then to decrease the percentage of one element by regular gradations to zero until all three elements have been so treated, which will give combinations all the way from 5-5-5 to 5-5-0; from 5-5-5 to 5-0-5; and from 5-5-5 to 0-5-5.

Special attention is being given to the problem of varieties of bright tobacco. Ten of the most promising varieties were planted in the spring of 1919 on 1/10 acre plats which will receive similar cultivation and fertilization, in order to secure comparative data on the relative merits of these varieties.

Appomattox, Appomattox County.—Experiments are under way to determine the best fertilizer combination for dark tobacco. Tobacco is being grown in a three-year rotation with wheat and clover. The fertilizers are applied before planting the tobacco crop. There are twelve plats, and the project was begun in 1918. In the spring of 1919, sixteen additional plats were included in the same project.

A series of crop rotations is being followed to gain information on local farming problems. A two-year rotation consists of corn with rye and vetch seeded at the last cultivation of the corn, and soy beans planted the following spring. A three-year rotation consists of tobacco, wheat and clover. A four-year rotation consists of corn and tobacco, wheat and mixed grasses two years in succession. Still another four-year rotation consists of tobacco, soy beans, wheat and clover.

Extensive variety tests are being conducted for the benefit of the farmers in this region. The crops involved are eleven varieties of corn, five varieties of dark tobacco, five varieties of bright tobacco, seven varieties of potatoes, five varieties of winter oats, six varieties of spring oats, three varieties of rye, twelve varieties of wheat, eight varieties of cowpeas, six varieties of soy beans, and nine varieties of tomatoes.

Experiments are being carried on in co-operation with the Department of Plant Pathology on the control of tomato blight by spraying.

A test is being made on the relative value of bright and dark tobacco on the typical gray soils of the county.

The experiments on the culture of alfalfa have shown that this crop can be grown successfully here by proper attention to soil, fertilizers and culture.

Bowling Green, Caroline County.—The experiments at this station are concerned with the growing of sun-cured tobacco and other crops. The leading feature of the work at this station has been a fertilizer test, using different elements of plant food, different combinations, different amounts, and fertilizer materials from different sources, applied directly to tobacco, comparing these fertilizers on 1/20 acre plats. A study is also made on the residual effects of these fertilizers on four other crops in the rotation with tobacco, namely, wheat, grass, corn and peas. This test has extended over ten years; five fields were used with two complete rotations on each. The results of this work have proved conclusively that phosphoric acid is the limiting factor in crop production on this soil, and that nitrogen and potash are ineffective unless phosphoric acid is also supplied to the soil. A complete fertilizer gives satisfactory results on this type of soil. These experiments have shown a gradual depletion of soil fertility on check plats under continuous cropping to which no fertilizer was added; but heavy applica-

tions of a complete fertilizer not only increased crop yield, but at the same time progressively improved the land. Comparative studies of tobacco varieties and strains have been made under uniform conditions for the past ten years. The results have shown that the variety Orinoco (of which there are eight strains) is best for this section; the strain Narrow Leaf Orinoco stands at the head of the list.

The varieties of corn which have proved most profitable here are Cocke's Prolific, Boone County and Collier's. The bearded varieties of wheat have given best results.

The tobacco horn worm has been controlled successfully by dusting the plants at the proper time with powdered arsenate of lead. It was found that Paris Green, under certain conditions, caused burning of the plants when used as an insecticide to control the horn worm.

Holland, Nansemond County.—The leading features of the work at this station are fertilizer experiments with peanuts and cotton. The tests with cotton show that both phosphoric acid and potash are essential to the successful growth of this crop. During the past two years no potash was applied to cotton in certain plats on the rotation series owing to scarcity and high price of potash; the result has been a poor yield of cotton. Where no potash is used there is a tendency for rust to check the growth of the plants too early and in consequence there are many immature bolls on the plant at the end of the growing season. The other three crops in this rotation, namely, corn, peanuts and soy beans, show no ill effects from the lack of potash.

Special attention is given to the use of lime on the crops commonly grown in this region. Results so far indicate that lime in liberal quantities may be used to replace gypsum or land plaster in peanut growing.

Variety studies are being made with the more important farm crops of the region, namely, corn, cotton, peanuts, soy beans, cowpeas, potatoes, wheat and oats. Austin, Brown and Mammoth Yellow soy beans have proved most satisfactory. Cowpeas have not proved as satisfactory as soy beans. Only the short staple varieties of cotton can be grown successfully here, the most successful varieties being Trice, King and Simpkins.

A test is being made to compare nitrate of soda and cyanamid for top dressing corn.

Lightfoot, York County.—The experimental work at this station deals primarily with alfalfa. The soil on this farm is Norfolk fine sand, and it is representative of an extensive area in the Tidewater region of the State. In the summer of 1918 seeding was made of several varieties of alfalfa, fertilizer tests with alfalfa were begun, top dressing tests and crop rotation ex-

periments in which alfalfa is one of the crops. The greatest difficulty in growing alfalfa on these light sandy soils is to maintain the stand. The experimental work at the Williamsburg station, which was discontinued in 1918, showed that top dressing alfalfa with commercial fertilizers was efficacious in maintaining the stand; this question will be tested in a larger way at the Lightfoot station.

Hog pasture experiments are in progress at this station, the object being to provide a succession of crops through the long growing season and to determine what crops give best results in raising hogs on pasture. This project is being carried on co-operatively with the Department of Animal Husbandry.

Charlotte Court House, Charlotte County.—The work at this county station is supervised by the Virginia Agricultural Experiment Station and financed by the State Board of Agriculture. The chief line of work here is a study of fertilizers for dark tobacco and crops grown in rotation with tobacco. The tobacco experiments were interfered with by the appearance of a destructive disease known to the farmers as "wild fire."

Variety tests of wheat, corn, cowpeas, soy beans, oats, rye and potatoes, are under way. Substantial progress has been made on the reclamation project, which is an effort to bring under successful cultivation a piece of land that was "worn out" and abandoned. A test is also being made on the value of Phos-pho-germ in comparison with standard fertilizers.

Staunton, Augusta County.—The work at this county station is supervised by the Virginia Agricultural Experiment Station and financed by the State Board of Agriculture. Satisfactory results were secured from the series of one-acre demonstration plats, which are being handled under a good rotation and fertilizer system. The crop yields from these plats were excellent.

Fertilizer tests are being made on corn, soy beans, wheat and grass in a five-year rotation on plats 1/30 acre in size. The fertilizers are applied to the soy beans, wheat and first-year grass. The most noteworthy feature of this test to date is the fine results from the use of phosphatic fertilizers. Acid phosphate (16 percent) gave best results. Nitrogen gave paying results on grain crops only in cases where the clover failed to stand before the grain crop came on the land.

A test is being made of home-mixed fertilizers in comparison with factory-mixed goods. Plats 1/15 acre in size are used for this purpose.

Experiments on dates and rates of seeding wheat show that October 1 is the best time for seeding wheat in this section.

Varieties of the leading farm crops for this section are being studied. Red Wonder, Fulcaster, Stoner and Leap's Prolific wheat are giving good results. Leaming, Gold Standard, Reid's, Boone County White, Casey's Purebred and Collier's Excelsior are promising and satisfactory varieties of corn. Among soy bean varieties Hollybrook, Haberlandt and Wilson have given fine results.

A test is under way to compare Phos-pho-germ with other fertilizers.

Martinsville, Henry County.—This station is supervised by the Virginia Agricultural Experiment Station and financed by the State Board of Agriculture. The two rotations carried out in conjunction with fertilizer tests show conclusively that acid phosphate pays well on our soils, and crops respond to it better than to any other fertilizer element. Variety tests are being conducted at this station dealing with the leading farm crops of the section. Work along lines of grass culture indicates that early fall is the best time for seeding grass. A reclamation project is under way. A test is being made on Phos-pho-germ. Experiments have been made with alfalfa culture for a number of years, and this crop has succeeded very well here. Considerable attention is given to the testing of varieties of the leading farm crops.

Animal Husbandry Department

Wintering dairy heifers (State Fund).—The object of this experiment is to determine the relative value and economy of different concentrated feeds for dairy heifers. Cottonseed meal, copra nut meal and velvet bean meal were used. The roughage in each case was corn silage. Purebred Holstein-Friesian and Jersey heifers were put on the test. Best results were secured from feeding cottonseed meal.

Sheep breeding (State Fund).—The object of this investigation is to determine the relative merits of crossbred lambs from grade ewes and purebred bucks. In the summer of 1918, 124 western grade ewes were purchased for this work. Purebred Southdown, Dorset and Shropshire bucks were procured. The ewes were divided into three lots for the matings. Other conditions being equal, it may be determined which of the sires will produce the best grade of offspring from the standpoint of early lambs for market purposes.

Hog pasture experiment (State Fund).—The plan is to provide a succession of pasture crops for hogs and to supplement the pasture with corn and tankage. Fifty purebred Duroc-Jersey gilts were purchased for the work. These were divided into five lots. One lot receives no feed except the

pasture. One lot runs on pasture and in addition has free access to a self-feeder containing corn and tankage. The other three lots will receive each respectively 25, 50 and 75 percent as much corn and tankage as is consumed by the lot having free access to the self-feeder. Both gains and economy in gains will be considered in the final results. The experiment is now progressing in a satisfactory manner.

Holstein-Friesian Sires (State Fund).—Studies were made along the lines of a basis for selecting Holstein-Friesian sires for high yearly production. These studies were based upon the records available in the official Blue Book and Herd Books of the Holstein-Friesian Association of America.

Dairy Husbandry Department

Protein and energy requirements for milk production (Adams Fund).—The chemical department and the dairy husbandry department are working jointly on this project, which is being investigated at the present time under three phases or subprojects. The work was initiated in 1913, at which time ten Holstein-Friesian cows were bought for this experiment. At the present time there are twenty-five females in the herd, thirteen of which are milking cows. Five of these cows are used permanently in *subproject b,* and from the remaining eight enough animals can be selected for the work in *subproject a.* Male calves from these cows are being used in *subproject c,* which deals with protein requirements for the growth of calves.

During the year a shed was built in the barnyard to provide shelter for the animals when they are turned out of the barn. A concrete floor will be made in this shed to facilitate the removal of excrements and to improve the cleanliness of the yards. Stalls were erected in the barn for handling the young cattle in the digestion trial referred to under *subproject c.*

Subproject a.—Protein and energy requirements for milk production.—These experiments have for their purpose the determination of the amount of digestible protein and net energy required above maintenance to produce a definite quantity of milk. Three groups of cows, each group containing two animals, are used in each digestion trial, which covers a period of 150 days. A basal ration is fed to all groups which supplies enough digestible protein and net energy for maintenance and milk production of each animal according to its weight and the amount of milk produced at the time. The cows in group I are fed the basal ration and one pound of protein in the form of blood meal. The cows in group II are fed the basal ration and one pound of carbohydrates in the form of corn starch. The cows in group III are fed the basal ration alone.

The 150-day trial is divided into three 50-day periods after each of which the groups are alternated, so that at the end of the trial each group will have been on the three rations. During the last 10 days of each 50-day period, a digestion trial is made with one animal from each group.

The results of the work under this subproject have shown that estimated requirements for maintenance of individual animals introduce errors into the calculations which are inconsistent with the general accuracy of the rest of the work and that maintenance trials are necessary if uniformity is to be secured in the final results. In the future each 150-day feeding trial will be followed by a maintenance trial.

Subproject b.—The effect of high protein and high energy rations in feeding dairy cows.—The object of this experiment is to determine the effects of feeding to dairy cows rations containing on the one hand excessive amounts of protein and on the other hand rations containing small amounts of protein with excessive carbohydrates. It was thought that although the results obtained from the feeding under *subproject a* might show that an addition of protein above the requirements is beneficial from the milk producing standpoint yet an excessive addition might prove injurious in other ways. For the same reason the excessive addition of carbohydrates was made a part of the study. The main points under investigation are the effects of these kinds of rations on the physical condition, metabolism, growth of offspring and composition and amount of milk.

Four cows were used in this experiment. Two of the cows were fed the high protein ration containing 7 pounds of gluten meal, 2 pounds of cottonseed meal, 2 pounds of bran, and 40 pounds of silage. The other two cows were fed the high energy ration consisting of 9 pounds of corn meal, 2 pounds of bran, and 40 pounds of silage. These cows have been on these rations since 1915.

In both groups at the time of the trials, the requirements for digestible protein, net energy and dry matter were supplied by the two rations when calculations are made with average digestion coefficients.

The high energy cows had been milking for some time and when fresh they did not have sufficient digestible protein to maintain the milk flow; but the amount of net energy was sufficient. The result was a diminution of the digestibility of the protein, crude fiber, nitrogen-free extract and ether extract, the cows rapidly became emaciated and the milk flow was reduced. The weakness of the cows became so marked that they could hardly get on their feet after lying down. They declined from a normal weight of 1,000 pounds to 850 pounds. When the milk flow decreased, the second trial indicates that the digestibility of the protein increased and

also that of the nitrogen-free extract, thus allowing the cows to gain weight, the rapidity of gain increasing as the lactation period advanced.

The decrease in digestibility resulted in a decrease of available net energy, in the case of the high energy cow on the first trial, until the requirements for energy were just met, then the decrease stopped. The cow on this ration in the second trial, being at the end of her lactation period, was then securing an excess of both digestible protein and net energy and was putting on flesh rapidly.

The decrease in digestibility resulted in an increase in the amount of dung excreted. There was an average percent of moisture in the dung. Cows on the high protein ration excreted from two to four times as much urine as did those on the high energy ration. This points to a need for more water for cows on such rations.

The data relating to coefficients of digestibility of the cows on the high energy ration are confirmed in both trials.

Excess protein in a ration, in such quantities as fed here, seems to induce the formation of milk fat from either protein or carbohydrates of the food.

These experiments show that the high energy cows could not have used more than 0.345 of a pound of digestible protein for maintenance. This amount is much below the standard allowance.

Subproject c.—Protein requirements for the growth of cattle.—This phase of the feeding work was undertaken at the suggestion of the Agricultural Committee of the Council of National Defense and is being carried out according to a plan made by Dr. H. P. Armsby of the Pennsylvania Institute of Animal Nutrition. The plan is to feed either beef or dairy calves, old enough to consume exclusively dry feed, upon two different planes of protein intake but with equal net energy supply. The low protein ration is to supply little more than the minimum of protein theoretically required, while the high protein ration is to supply about the amount demanded by current feeding standards. The energy supply is sufficient to support normal growth but not sufficient to cause fattening.

The proteins in the two rations are to be derived in fixed proportions from identical feeding stuffs and an ample supply of ash ingredients and vitamines is to be provided. Any necessary adjustments in the bulk of the rations are to be made by varying the amount of straw; and necessary adjustments of the energy supply are to be made by using greater or smaller amounts of commercial starch.

Obviously the animals to be compared must be as nearly alike as possible. The plan contemplates a comparison of the animals by pairs, one animal of each pair receiving the high protein and one the low protein ra-

tion. The animals of each pair should be of the same breed, but not necessarily purebreds, and of approximately the same age and weight at the beginning of the experiment.

Animals of suitable size, breeding and age could not be secured when this experiment was initiated. The four calves that were put on trial were ordinary farm calves of the same breed and closely related. The trial extended over a period of six months, from March 25 to September 25, 1918. Two digestion trials were conducted during the trial; the first from May 15 to 25, and the second from September 7 to 14.

A second group of calves is now on trial. These are male Holstein calves of practically the same age and sired by the same bull. They were well developed when put on the trial. The trial is progressing in a satisfactory manner.

Department of Plant Pathology and Bacteriology

Black rootrot of apples (Adams Fund).—A study of this disease in several orchards has been continued as in previous years. This phase of the problem involves the annual mapping of the orchards to determine the progress of infection from diseased to healthy trees and the practicability of replanting in infested soil.

Promising results have been obtained in the tests of the susceptibility of root stocks of different varieties of apple, and it now seems probable that the control of rootrot will be achieved by selection of resistant root stocks. A number of self-rooted apple trees of different varieties were inoculated with cultures of *Xylaria* in the spring of 1917, and planted at Blacksburg. Marked variations in the susceptibility of the roots of different varieties were obtained. On the most suspectible varieties the infection had progressed during two years, from the point of inoculation on a lateral root two inches from the crown, into the crown, which it had completely girdled. One variety appeared to be immune. No infections were obtained from the inoculations of this variety, but since the number of trees of this variety inoculated was small, it does not seem advisable to record more than a promise in this respect until verification of these results are obtained with a larger number of trees. Additional tests of this variety in comparison with the common root-stocks are now in progress. Inoculations have been made on a number of trees at Crozet, Virginia, and a number have been set in several orchards as replants following trees that were killed by rootrot.

The relations between parasitic fungi and their host plants. (Adams Fund).—Some of the results obtained from the study of the susceptibility of varieties of beans to the rust fungus *(Uromyces appendiculatus)* were

published during the year in Bulletin 220. In this bulletin it is shown that the losses from bean rust may be prevented by the proper choice of resistant varieties and the avoidance of susceptible varieties. A number of resistant varieties of good quality are recommended. A paper involving some of the more technical aspects of the work is in preparation. Additional work is in progress on the heredity of rust resistance. The progeny of a number of crosses between resistant and susceptible varieties is being tested in comparison with the parental strains. Some selections made from resistant individuals which appeared in some of the plantings of susceptible varieties last season are also being tested. A historical study of the progress of infection in resistant and susceptible varieties is under way.

Tomato diseases (Hatch Fund).—Spraying experiments on the control of leaf blight *(Septoria)* of the tomato were conducted at Blacksburg on the plats of the experiment station and on the farm of Mr. H. D. Didier near Amsterdam. The soap-Bordeaux mixture developed by Pritchard and Clarke and described in C. T. and F. C. D. Circular 4 of the U. S. Department of Agriculture, was used at both places. Five applications were made at each place. The results of spraying were marked, both in appearance of the foliage and the yields, which are as follows:

Yields of ripe tomatoes on plats at Blacksburg and Amsterdam sprayed with soap-Bordeaux and not sprayed. 1918.

		Total ripe fruit	Ripe fruit per acre	Gain per acre
Blacksburg, Va. Sprays applied July 6, 15, 27; August 5, 20	Sprayed plat	833 lbs.	291 bu.	72 bu.
	Check plat	541 lbs.	219 bu.	
Amsterdam, Va. Sprays applied July 5, 25; August 8, 17, 27	Sprayed field 2.26 acres	328 bu.	145 bu.	77 bu.
	Check field 5.19 acres	354 bu.	68 bu.	

Our previous experience with Bordeaux mixture alone had been disappointing. There had been little benefit from spraying. The soap-Bordeaux seems to be a much better material for the control of leaf-blight. It spreads and covers thoroughly, and is not easily washed off by rains. It will be noted from the table that the gain per acre in ripe fruit from spraying was practically the same at Blacksburg (72 bu.) and at Amsterdam (77 bu.). In addition to the gain in ripe fruit, there was a very marked increase in green fruit on the vines of the sprayed plats at the end of harvest. At

Blacksburg the green fruit on the sprayed plat amounted to 152 bu. per acre, while the check plat had only 19 bu. per acre. Cost accounts at Amsterdam showed a net gain of $22.80 per acre from spraying.

A fruit rot of bacterial causation which appeared in the plats at Blacksburg is being made a special study by Mr. S. A. Wingard. The organism has been isolated and has been used for a large number of infections on tomatoes in the greenhouse. It requires a wound or crack for infection, and is virulent on green fruit. Ripening fruit is slightly or not at all affected.

Seed of the wilt resistant Norton tomato which was obtained from the U. S. Department of Agriculture, was distributed to a number of commercial growers and gardeners for tests in soil infested with Fusarium wilt. The reports from these tests were unanimous to the effect that the variety proved to be resistant to wilt, productive and of excellent quality. In one of the tests which the writer observed, Norton plants showed no loss from wilt, while plants of Brimmer in the same rows were a complete failure. Seed of this variety together with three other wilt resistant varieties received from Washington are being disseminated on a larger scale this year.

Leaf spot of tobacco (Hatch Fund).—A preliminary study of the angular leaf spot of tobacco begun in 1917, has been completed and published in the Journal of Agricultural Research for February 24, 1919. This paper deals with the etiology and pathology of the disease which is shown to be due to an organism which is described as a new species, *Bacterium angulatum.* The disease is very destructive in wet seasons, and the tobacco growers have as yet no means of controlling it. Studies on the relation of the prevalence of the disease to sources of seed, treatment of seed beds, fertilizers and varieties which are under way, should point to the most likely methods of control. The disease was found on seedling plants in a number of beds and evidence has been obtained to show that the disease is carried to the field and established there from the seed bed.

Another disease which has been described from North Carolina as "wild fire" also occurs on tobacco in some sections of the State, and is also very destructive. It is quite like angular leaf spot in some respects, but can be distinguished by the shape of the spots which are circular instead of angular. Wild fire is also apparently disseminated from the seed bed.

Plant disease survey (Hatch Fund).—The most important feature of the survey work for the year consisted in a survey to determine the distribution of the nematode disease of wheat. The survey was conducted in co-operation with the Plant Disease Survey of the U. S. Department of Agriculture. Four scouts were provided for the work. Most of the wheat

growing counties of the State were visited and a large number of lots of wheat were examined. As a result of this survey together with information which had accumulated prior to it, the nematode disease is now known to be present to some extent in twenty-eight counties, and to be rather generally distributed throughout the State.

A field test on seed treatment and resistance of varieties to the nematode disease has been completed, but the tabulation of results has not been finished. It was apparent that any method which would remove the nematode galls from wheat would make it suitable for seed. There was some variation in the resistance of varieties of wheat, but all were infected to a considerable extent. Work in progress involves studies on the length of rotation and crops to be grown in the rotation on nematode infested soils.

A mass of miscellaneous data on the distribution and losses from plant diseases in the State has been accumulated and has been published during the year in the Plant Disease Bulletin.

Department of Entomology

The entomological work is in charge of the State Entomologist, but the experimental phases of this work are closely affiliated with the Experiment Station.

During the year the investigational work of this department was restricted to a few projects. The studies on aphids attacking apple trees were completed and a paper on this subject by Dr. Smulyan forms a part of this report.

Control of woolly aphis.—For a number of years the department has given considerable attention to this problem. The woolly aphis ranks as one of the most important fruit pests throughout the southern states. Its injuries are particularly noticeable on young apple trees in nurseries and orchards. When the trees become infested there is no practical remedy available for eradicating the pest. During the past season important facts have been learned regarding the time and manner in which the trees become infested.

The Oriental peach moth.—Within the past year a study of this new fruit pest has been undertaken. A field laboratory has been established at Leesburg and practical control work is being carried on in Fairfax County. The insect is not definitely known to exist in the State outside of the northern counties within a radius of fifty miles of Washington City.

Insects attacking field crops.—During the year attention has been given to the collection and study of insects attacking our important field

crops, particularly alfalfa, clover, corn, wheat, tobacco and peanuts. These studies are being carried on by the several inspectors and assistants as time permits and it is hoped that in the near future lists of the injurious species of insects may be prepared.

ON THE DISAPPEARANCE OF SOIL NITROGEN*

By W. B. Ellett.

The Virginia Experiment Station has a series of plats located at Blacksburg, Virginia, on a soil that is known as Hagerstown loam. These plats were provided with walkways three feet wide between the plats so that in cultivating, the fertilizer from one plat would not be carried to one of different treatment. The cultivation given to the plats was the same in all cases. These plats have been planted with corn continuously since 1907. The corn was harvested and the land allowed to remain bare until the following spring, when it was plowed again. This treatment was followed the first five years, and at the beginning of the sixth year, 1912, a clover was sown on all the plats at the last working of corn, with a view of increasing the nitrogen and organic matter of the soil. The clover was turned under between the first and fifteenth of May. The growth of clover was poor on all plats except those receiving stable manure and complete fertilizer. In 1917 rye was substituted for clover to increase the organic matter in the soil. I wish to call your attention to plats 18 and 19 of this experiment. The treatment on plat 18 has been an annual application of burnt lime at the rate of 1,200 pounds per acre. The burnt lime was water slaked before applying. Nothing has been applied on plat 19.

The analyses of samples of soil taken from these two plats do not show a marked diminution of the nitrogen content, although the experiment conducted at the Pennsylvania Experiment Station, where burnt lime and ground limestone were compared, is still being cited as a basis for the unqualified denunciation of the use of burnt lime and slaked lime, because an analysis of the soil showed that the nitrogen content had diminished where burnt lime was used in the experiment. Hopkins, in his "System of Permanent Agriculture" calculates the nitrogen percentage into pounds per acre, and finds a difference of 375 pounds of nitrogen or the equivalent of 37½ tons of manure was lost by the application of the caustic lime. I am of the opinion that the difference shown in the analysis is due to the inability to secure accurate samples of soil for analysis, and after the samples are secured an error, due to the manipulation of the method, would account

*The data contained in this paper was presented at the conference of Southeastern Experiment Station Workers at Knoxville, Tennessee, April 29 and 30, 1919.

Table 1.—Showing yield of grain, amounts of nitrogen, potash and phosphoric acid removed from the soil by the crop and the nitrogen content of the soil on limed and not limed plats for a period of twelve years.

Year	Plat 18—1200 pounds burnt lime per acre: Yield of grain in bushels per acre	Plat 18: Plant food removed from the soil calculated in pounds per acre: Nitrogen	Plat 18: Potash	Plat 18: Phosphoric acid	Plat 18: Percent of nitrogen found in the soil	Plat 19—Check, not limed: Yield of grain in bushels per acre	Plat 19: Plant food removed from the soil calculated in pounds per acre: Nitrogen	Plat 19: Potash	Plat 19: Phosphoric acid	Plat 19: Percent of nitrogen found in the soil
1907	43.93	73.69	56.28	33.17	.105	44.46	68.53	48.66	30.68	.105
1908	53.57	90.90	70.05	40.95	.123	47.14	83.53	66.55	37.74	.111
1909	52.50	76.21	50.98	33.97	.112	39.64	64.16	47.58	28.82	.116
1910	39.65	61.54	43.97	27.56	.112	30.00	49.22	36.91	22.82	.114
1911	47.68	71.46	49.38	31.92	.104	34.82	65.43	54.24	29.65	.113
1912	53.60	76.83	50.71	34.21	.106	26.80	49.69	40.83	22.51	.106
1913	51.50	74.36	49.47	33.13	.114	34.30	53.68	38.64	24.05	.104
1914					.107					.111
1915	52.50	70.19	42.72	31.09	.100	30.54	47.45	33.93	21.25	.098
1916	62.81	81.23	47.35	35.88	.099	45.30	68.55	47.82	30.64	.097
1917	27.19	52.87	44.79	24.01	.101	11.25	28.26	27.29	12.99	.104
1918	42.32	53.62	30.38	23.64	.098	22.10	30.20	18.88	13.40	.106
Totals	527.25	782.90	536.08	349.53		366.35	608.74	461.33	273.85	
Average percent of nitrogen found in soil					.107	Average percent of nitrogen found in soil				.107

for most of the difference shown by the analysis. .005 of a percent of nitrogen, which is well within the experimental error of an accurate chemist when he determines nitrogen, would be equal to 100 pounds of nitrogen, if calculated to two million pounds of soil, and if the soil weighed three million pounds to the first nine inches, the error would be equal to 150 pounds of nitrogen.

The results of the analyses of the samples of soil from plats 18 and 19 do not show that the burnt lime burnt up or has depleted the native soil nitrogen. If we consider the crop returns from the two plats, the burnt lime has made conditions more favorable for corn and larger yields were produced, with a heavier draft on the soil of the store of nitrogen, potash and phosphoric acid. The heavier draft of these plant food elements by the corn on plat 18 is due, in my opinion, to the amelioration of the physical condition of the soil.

Table 2.—Showing the difference between total yield of grain and total amounts of plant food removed from the soil of limed and not limed plats for a period of twelve years.

	Total yield of grain in bushels per acre	Total amounts of plant food removed in pounds per acre		
		Nitrogen	Potash	Phosphoric acid
Plat 18	527.25	782.90	536.08	349.53
Plat 19	366.35	608.74	461.33	273.85
Difference	160.90	174.16	74.75	75.68

TWO METHODS FOR DETERMINING BORAX IN MIXED FERTILIZERS COMPARED

By H. H. Hill

Since the beginning of the World War very little potash has arrived in this country from France and Germany for use in fertilizer manufacture, and fertilizer dealers have been unable to fill their orders from these sources. The principal sources of potash salts at present are the Chilean and Searles Lake, California, deposits.

The Bureau of Soils of the United States Department of Agriculture has investigated these sources of potash and recommends their use under certain limitations. Furthermore, Congress has encouraged the production

of potash from domestic sources, but, unfortunately, these materials contain borax in varying quantities which may restrict their use to a more or less extent. The Bureau of Soils has determined that the limit of safety is two pounds of anhydrous borax per acre, when applied in the drill and ten pounds per acre when sown broadcast. Therefore, an order was sent out to all fertilizer manufacturers and dry mixers not to sell mixed fertilizers containing more than 0.1 percent of anhydrous borax without plainly showing the amount of borax on the container. This was not done to exclude borax, but to enable these materials to be used during the war emergency, and to prevent damage to crops by the intelligent use of these salts by the farmer. It is believed that the amount of borax in American potash salts can be materially reduced by proper treatment so as to make them comparable with potash salts from European sources.

One of the problems that has confronted the agricultural chemist in this connection is the estimation of borax in potash materials as pure salts, and after they have gone into mixed goods.

Two methods for the estimation of borax have been proposed. The first by Carpenter, Breckenridge, and Magruder, is based on the liberation of boron as methyl borate. The solution containing methyl borate is made alkaline with caustic soda, evaporated and ignited free from organic matter. Mannitol is added and tenth normal caustic soda is run in to neutrality. The amount of standard caustic soda has a definite value in boric acid, borax and anhydrous borax, the results being expressed in any of these three forms.

The second method is by W. H. Ross of the Bureau of Soils, and R. B. Deemer of the Bureau of Plant Industry of the United States Department of Agriculture. These investigators have used direct titration methods. They treat the subject under the following conditions:

1. Determination of borax in mineral salts, when the sample contains soluble phosphates or iron and aluminum salts and the borax is present in small amount (1 percent or less).

2. When the borax is present in small amount and soluble phosphates or iron and aluminum salts are absent.

3. When the sample contains soluble phosphates or iron and aluminum salts, and the borax is present in relatively large amount (in excess of 1 percent).

4. When the borax is present in relatively large amount and soluble phosphates or iron and aluminum salts are present.

5. Determination of borax in mixed fertilizers. When the borax is present in small amount (0.5 percent or less).

6. When the borax is present in relatively large amount (in excess of 0.5 percent).

7. Determination of borax in straight organic materials.

The two methods above have been tested very thoroughly in this laboratory, one of which has given very satisfactory results with boric acid, borax and mixed fertilizers. When the method of Carpenter, Breckenridge and Magruder was used losses occurred as a result of the ignition of the residue after evaporation. This occurred when the heat was kept below redness and in using a pure boric acid solution the theoretical quantity could not be obtained. With mixed goods the results were equally as unsatisfactory.

By the method of Ross and Deemer very satisfactory results were obtained with pure salts and with mixed goods. With a standard boric acid solution containing ten grams of boric acid per liter, results which deviated from theory by less than one milligram were obtained. In this case five grams of boric acid were dissolved in 500 cc. of water and 10 cc. taken for analysis. This portion represented 0.1 gram of the original material. The distillation method of Carpenter, Breckenridge and Magruder gave results very much lower than theory.

Assuming that if the former method gave results with pure salts of boron approaching the theoretical value of the standard it would be reasonable to assume that the method would give fairly good results with mixed fertilizers, as it is with these mixtures, containing organic matter, that the fertilizer chemist experiences the greatest difficulty in the estimation of borax. For the determination of borax in mixed goods, modification No. 5 by Ross and Deemer was selected. This method, with a few added details, is as follows: Have at hand the following reagents:

1. A 10 percent solution of barium chloride.

2. Powdered barium hydroxide.

3. Standard boric acid prepared from recrystallized boric acid.

4. Tenth normal sodium hydroxide that has been standardized against boric acid. This solution should be free of carbonates. This may be done by making a saturated sodium hydroxide solution so that any sodium carbonate present will be precipitated when the solution is allowed to stand in a vessel from which carbon dioxide of the air is excluded.

5. Hydrochloric acid solution, about N/10.

6. Neutral mannite (mannitol).

7. Methyl red solution prepared by dissolving 0.1 gram in 100 cc. of a hot 50 percent solution of alcohol and water and filtering.

8. Phenolphthalein solution prepared by dissolving 1 gram of phenolphthalein in 100 cc. of alcohol.

Weigh 1 gram of the powdered sample of mixed fertilizer on a 11 c. m. filter, and wash well with hot water into a 250 cc. beaker. Washing to a bulk of 125 cc. appears to be sufficient. Heat the solution to boiling and add 15 cc. of barium chloride solution and sufficient powdered barium hydroxide to give an alkaline reaction. Boil for thirty minutes, or until any ammonia present has been expelled, taking care that the solution remains alkaline throughout the period of boiling; filter on a 15 c. m. paper, catching the filtrate in a 500 cc. Erlenmeyer flask. Acidify the filtrate with a few drops of N/10 hydrochloric acid, using an excess equivalent to a few cc. of solution. Attach the flask to a reflux air condenser, taking proper precautions as to the length of reflux tube, so as not to allow the vapors from the boiling solution to escape. Boil the solution for fifteen minutes to expel carbon dioxide, cool by placing the flask in cold water. Add two drops of methyl red and then N/10 sodium hydroxide until the color of the solution changes from pink to yellow. If the neutral point has been exceeded, or if there is any doubt as to this, the pink color may be restored by adding a few drops of hydrochloric acid (reagent 5) and the color then changed to yellow again with the minimum amount of the standard sodium hydroxide solution. A gram or two of neutral mannite and a few tenths of a cc. of phenolphthalein solution are now added, the burette reading noted, and the solution again titrated with the standard sodium hydroxide solution until a pink color develops. A little more mannite is now added and if the pink color disappears the addition of the standard alkali is continued until a pink color again appears. This is repeated until the addition of mannite has no further action on the end point. If the content of boric acid in the solution titrated is low, one addition of mannite is usually sufficient. By noting the volume of the standard alkali required in the titration after the addition of the mannite, the quantity of borax in the sample may then be readily calculated, knowing that 1 cc. of a N/10 sodium hydroxide solution is equivalent to 0.0062 gram of boric acid, or to 0.00505 gram of anhydrous borax.

In checking this method by the use of pure salts a solution of boric acid was used, 10 cc. of which were equivalent to 0.1 gram H_3BO_3. The first portion required 16.2 cc. N/10 sodium hydroxide solution and the second 16.1 cc., equivalent to 0.10044 and 0.09982 gram H_3BO_3, respectively. The average of these two determinations deviates from theory by 0.00013 gram, which is sufficiently accurate for all purposes. When this solution was run by the distillation method of Carpenter, Breckenridge and Magruder, the results were very unsatisfactory. The results with $Na_2B_4O_7$, 10 H_2O were slightly off on account of the change in the water of crystallization of the same, but when the borax was dehydrated theoretical results were obtained. In addition to the above salts five samples of Trona

potash containing fairly large quantities of borax were analyzed. The duplicates with these salts were very satisfactory. In the estimation of borax in fertilizers the greatest difficulty is experienced with mixed goods containing organic matter. The extracted coloring matter of the sample has some effect in obscuring the end point when methyl red and phenolphthalein are used as indicators, but if one gram samples of the mixed fertilizers are taken, and sufficient water added, the brown color is diminished to such an extent that a fairly sharp end point is secured.

Three samples of mixed goods were analyzed in order to determine the efficiency of the method in the presence of organic matter. Sample No. 1 was a mixture in 8-3-3 proportion; sample No. 2 was 8-7-5; and sample No. 3, 7-5-5. According to the above method of procedure the results were as follows: No. 1, 0.9 percent anhydrous borax; No. 2, 0.65 percent anhydrous borax; and No. 3, 0.58 percent anhydrous borax. In each case one gram samples were washed with boiling water to a bulk of about 125 cc. The duplicates were very close on all of the samples with variations of from one-tenth to two-tenths cc., which is a reasonable allowance.

In comparing these results with those of other chemists working independently of each other, a wide variation was observed. For instance, sample No. 1 gave .08 percent; No. 2, .09 percent; and No. 3, .06 percent. In carefully studying the methods it was decided that the high results were due primarily to the effect of the organic matter contained in the mixed fertilizers. Bearing this point in mind it was decided that the filtrate from the barium precipitation must be evaporated and ignited instead of titrating the filtrate direct as heretofore. Three additional five-gram samples were run, introducing this modification with the following results: Sample No. 1, .05 percent anhydrous borax; sample No. 2, .09 percent anhydrous borax, and sample No. 3, .06 percent anhydrous borax. With the exception of sample No. 1 these results were identical with those of the other chemists. Sample No. 1 was well within the limit of analytical error and all three samples were within the borax limit for fertilizers established by the recent ruling of the Secretary of Agriculture.

It is believed that with certain slight modifications in the details of the procedure, this method will be of great value in the determination of borax in mineral salts and mixed fertilizers. Unless a better method of purification of certain of the American potash salts used in fertilizer mixtures is sought, the ruling now in practice relative to the quantity of borax allowed in these mixtures makes the determination of borax imperative.

NOTE.—The chemical department can hardly agree with "American Fertilizer" of May 18, 1920, that "analysis for borax will never become routine work in the laboratory, and consequently there will be less thought given to simplifying the procedure which is quite complicated."

THE EFFECT OF FERTILIZERS ON THE GERMINATION OF SEEDS

By T. B. Hutcheson and T. K. Wolfe

In certain sections of the sate there is a practice among farmers of mixing grass and clover seed with the fertilizer before sowing. The question is often asked whether the fertilizer will increase or decrease the germination of the seed mixed with it, and to what extent. In portions of the state, especially where large applications of fertilizers are made to the acre, a part of the material is often applied in the row with the seed and the remainder is broadcasted either before or after planting. In case fertilizers and grains are distributed at the same time with the ordinary grain drills, the seed and fertilizer sown are placed in direct contact. The experiment herein reported was conducted to study the effect of different methods of applying fertilizers on the germination of seed.

Materials and Methods Used

A number of flats three inches deep were made from inch boards and each was divided into seven compartments one foot square. The first time the test was conducted the compartments were filled with soil from the experiment plats, classified by the Bureau of Soils as Hagerstown silt loam. The second time the test was conducted Norfolk sandy loam soil from Williamsburg, Va., was used. The fertilizer applications were made broadcast on some of the compartments, that is, distributed uniformly over the soil and worked in. The seed were then planted in rows. In some of the other compartments the rows were opened, the fertilizer distributed evenly in the furrow and the seed placed in direct contact with the fertilizer. The different kinds of seed used and fertilizers applied are shown in the tables which follow. The test was carried on in the greenhouse and the soil watered when necessary. The seed were counted before planting and the percentage of germination determined by counting the plants which appeared above ground after sufficient time had elapsed for normal germination of the seed. Seed were also planted in compartments receiving no fertilizer treatment to serve as a check on the fertilizers applied. In order to test the vitality of the seed used, the percentage of germination was determined by placing samples between moist blotters.

Table I.—Effect of fertilizers on the germination of seed on Hagerstown silt loam soil.

Fertilizer lbs. per acre	Method of application	Percentage of germination								
		Corn	Wheat	Rye	Oats	Soy-* beans	Alfalfa	Red Clover	Timothy	Redtop
Air slaked lime, 4000	In row	100	60	58	74	8	2	8	14	13
	Broadcast	98.67	79	84	99	65	45	61	47	78
Sulphate of Potash, 200	In row	98.33	76	56	100	59	57	65	46	71
	Broadcast	98.67	62	70	99	62	74	71	50	69
Muriate of Potash, 200	In row	96*	68	60	88	32	84	63	32	51
	Broadcast	97*	60	75	97	64	75	71	58	75
Nitrate of Soda, 200	In row	98.33	62	70	96	16	69	71	37	49
	Broadcast	93.33	61	60	96	62	66	63	47	59
Acid Phosphate, 300	In row	100	74	74	98	73	62	76	47	75
	Broadcast	100	62	62	100	73	67	62	59	68
Acid Phosphate, 300 Muriate of potash, 200	In row	100	60	82	88	32	62	70	24	46
	Broadcast	100	69	79	97	57	77	66	45	69
Nitrate of Soda. 200 Acid Phosphate, 300	In row	93.33	76	66	96	43	73	67	27	50
	Broadcast	98.67	71	64	95	70	68	68	47	42
Nitrate of Soda, 200 Muriate of Potash, 200	In row	93*	64	80	78	0	65	42	11	28
	Broadcast	99*	65	72	94	54	76	63	37	58
Nitrate of Soda, 200 Acid Phosphate, 300 Muriate of Potash, 200	In row	96.67	64	74	78	12	45	46	18	46
	Broadcast	98.67	64	66	97	60	74	57	65	60
Check		100	64	73	98	74	55	66	50	44
Percent germination in incubator		99	87.5	90	98.5	96	95	88.5	78.5	92.5

*These sets were conducted after the remainder of the corn tests, on account of being destroyed during the first test.

An average of the germination of all seed for each application on Hagerstown silt loam soil, shows that a higher percentage of germination is secured when the fertilizer is broadcasted than when applied in the row with the seed. There was but one exception, that of acid phosphate.

Table II.—Effect of fertilizers on the germination of seed on Norfolk sandy loam soil.

Fertilizer lbs. per acre	Method of application	Percentage of germination								
		Corn	Wheat	Rye	Oats	Soy-beans	Alfalfa	Red Clover	Timothy	Redtop
Air-slaked Lime, 4000	In row	81	64	50	64	40	0	3	7	8
	Broadcast	95	86	86	94	96	45	39	77	11
Sulphate of Potash, 200	In row	96	92	80	96	98	49	53	35	45
	Broadcast	98	70	74	90	94	80	84	19	10
Muriate of Potash, 200	In row	96	76	66	96	84	26	37	24	63
	Broadcast	95	78	76	80	90	85	61	32	29
Nitrate of Soda, 200	In row	96	80	78	86	94	56	63	51	76
	Broadcast	98	86	70	94	94	81	76	72	83
Acid Phosphate, 300	In row	98	70	80	88	92	58	57	77	77
	Broadcast	98	80	80	82	96	76	73	41	41
Acid Phosphate, 300 Muriate of Potash, 200	In row	96	52	58	82	88	20	25	38	53
	Broadcast	96	70	72	90	94	75	67	27	41
Nitrate of Soda, 200 Acid Phosphate, 300	In row	97	64	66	88	72	47	16	69	64
	Broadcast	97	74	78	92	96	86	65	70	43
Nitrate of Soda, 200 Muriate of Potash, 200	In row	97	66	62	96	54	9	18	54	31
	Broadcast	98	58	58	98	92	71	53	65	61
Nitrate of Soda, 200 Acid Phosphate, 300 Muriate of Potash, 200	In row	98	58	56	74	62	14	12	40	26
	Broadcast	96	58	86	86	96	78	67	45	54
Check		96	70	78	86	96	84	72	41	70
Percent of germination in incubator		98	86	94	90	89	89	81	89.5	84

An average of germination of all seeds for each treatment when the fertilizer was applied broadcast and in the row, shows the application made in the row in contact with the seed was more detrimental to germination in every instance save two; sulphate of potash and acid phosphate.

Summary

1. The effect of different fertilizers on the germination of seeds depends to a large extent on the soil type, kind of seed used, and the method of applying the fertilizer.

2. On the Hagerstown silt loam soil, averages of the germination percentage of all seeds tested for each treatment, when the fertilizers were applied in the row in contact with the seed and broadcast, show that the materials applied in the row were more injurious in every instance, except that of acid phosphate. This was also true on the Norfolk sandy loam soil with the exception of sulphate of potash and acid phosphate.

3. On both soil types used, the germination of corn was not materially lowered by the fertilizers applied, with the exception of lime placed in the row on the Norfolk sandy loam. In this instance the germination was reduced 15 percent.

4. Soy beans, when planted in Hagerstown silt loam soil, were substantially lowered in germination by all fertilizers, except acid phosphate. The fertilizers which were harmful seemed to be especially so when applied in the row. The injury on the Norfolk sandy loam was not so pronounced. On this latter type of soil, the materials applied in the row, with the exception of sulphate of potash, and nitrate of soda, were more detrimental than when applied broadcast.

5. In the case of wheat, rye, and oats, the effect of the different fertilizers applied was not very decided on either soil type.

6. The fertilizers, when applied in the row, were especially injurious to timothy in the Hagerstown silt loam soil, while the effect was not near so evident on the Norfolk sandy loam.

7. The harmful effect of the fertilizers on red top was more noticeable on the Norfolk sandy loam than on the Hagerstown silt loam.

8. With a few exceptions, the fertilizers applied, either broadcast or in the row did not lower the percentage of germination of alfalfa and red clover on the Hagerstown silt loam soil. However, the injurious effect was pronounced on the Norfolk sandy loam, especially when the materials were applied in the row.

9. When the average of the germination of all seeds under each treatment is considered, it will be found that in nine instances, on the Hagerstown silt loam soil, the germination was higher than on the Norfolk sandy loam. In nine cases the reverse was true. Of the nine instances of higher germination on the Hagerstown silt loam, five occurred when the seed was planted in the row with the fertilizer and four when the fertilizer had been broadcasted. On the Norfolk sandy loam, this occurrence was reversed.

10. There are certain growers who mix alfalfa and clover seed with the fertilizer before seeding. This practice is not to be advised.

11. As a whole, the materials used were much more injurious to the germination of the seed tested when applied in the row with the seed than when broadcasted and worked into the soil before planting.

12. Lime was especially detrimental when applied in the row with the seed. This effect was not so decided when the material was applied broadcast. With the exception of soy beans on the Hagerstown silt loam soil, lime applied broadcast did not lessen the germination of corn, wheat, rye, oats and soy beans. In most instances lime applied broadcast, decreased the germination of alfalfa, red clover, timothy, and red top on both types of soil.

13. Acid phosphate decreased the germination in eight instances. The decrease occurred six times on the Norfolk sandy loam, and twice on the Hagerstown silt loam soil.

Sulphate of potash decreased the germination in four instances on the Hagerstown silt loam and eight times on the Norfolk sandy loam.

The decrease in germination from applications containing either nitrate of soda or muriate of potash, or both, was noticeable in many cases.

14. When all the decreases and increases in germination were considered for the total number of different applications of materials made and the various seed used, it was found that on the Hagerstown silt loam soil there were 57 instances of decrease and 46 instances of increase of four percent or more. On the Norfolk sandy loam, there were 84 cases of decrease and 33 instances of increase of four percent or more.

15. It is difficult to give definite recommendations in regard to the use of fertilizers and state their probable effect on the germination of seeds. It seems that the results are modified by several factors. However, it would not likely be an advisable practice to decrease to any great extent the standard rates of planting seeds when fertilizers are used, especially when the seed and fertilizers are sown in contact. There is a tendency on the part of many growers to use less seed to the acre than ordinarily recommended for their soils. Particularly is this true in regard to wheat, and the seeds of hay and pasture grasses and clovers. Should a farmer have reason to believe that fertilizers will have an injurious effect on the germination of the seed to be planted, it would in most instances be the better practice to increase the rate of seeding rather than decrease the amount of fertilizer to be used. It would, in this case, be more advisable not to plant the seed in direct contact with the fertilizer, but first mix the fertilizer with the soil.

THE ROSY APPLE APHIS (*Aphis malifoliae* Fitch)[1]

By M. T. Smulyan

CONTENTS

[1]In adopting the name *A. malifoliae* Fitch for the "Rosy Apple Aphis" in this paper, the writer is following Baker and Turner (1, p. 321)[2]. In two former papers (9, p. 67; 10, p. 31) he used the name *A. sorbi* Kaltenbach, the name commonly used by American writers for this species since Sanderson's application of it in 1901 (7, p. 189-91). However, studies by Gillette and Taylor (5, p. 31-32) and Baker and Turner (1, p. 322-24) of Kaltenbach's *A. sorbi*, based on material collected on *Sorbus aucuparia* in the type locality and elsewhere in Europe, seem to indicate that the two species are distinct. Dr. Fitch's meagre description of *A. malifoliae*, made from winged viviparous females taken in October in Mercer County, Illinois, may be found in his First Report (4, p. 56-57). For a fuller discussion of the history and identity of the species the reader is referred to Sanderson (8, p. 149-51) and Baker and Turner (1, p. 321-25).

[2]Numbers in parenthesis refer to literature cited.

INTRODUCTION

The Rosy Aphis is the most injurious of the three species of aphids which commonly attack the cultivated apple in Virginia. It apparently occurs wherever apple trees occur, and by virtue of its decided preference for the leaves around the flower and fruit clusters is very destructive. The effects of its attack are seen in the serious curling and in the killing of the leaves, and, ultimately, in the stunted and misshapen fruit which are known

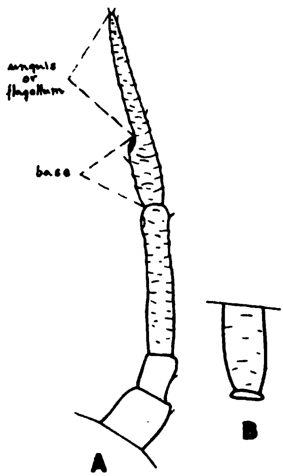


FIG. 1.—Antenna and cornicle of *Aphis maliafoliae* Fitch, about x 150.

as "aphis apples" or "gall apples." In years of abundance the entire crop of a tree may be thus ruined; and at such times it may also seriously injure young trees. It is perhaps also responsible for the "pitting" or spotting of the fully developed fruit (3, p. 14).

The other two species of aphids which are usually found with the Rosy Aphis on apple trees, and from which they should be distinguished, are the Apple-Grain Aphis (*A. prunifoliae* Fitch) and the Green Apple Aphis (*A. pomi* DeG.).

The principal studies of the insect were made in Blacksburg and vicinity and the conditions resulting from the comparatively high altitude—2400

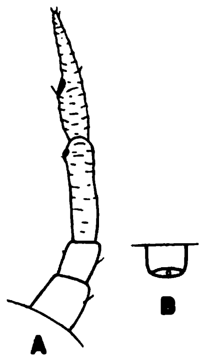


FIG. 2.—Antenna and cornicle of *Aphis pomi* DeG., about x 150.

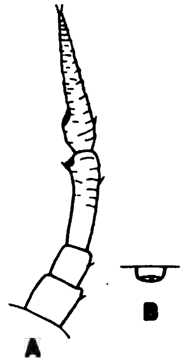


FIG. 3.—Antenna and cornicle of *Aphis prunifoliae* Fitch, about x 150.

feet—should be borne in mind in connection with the differences in the behavior of the insect elsewhere. No detailed study of the forms on plantains *(Plantago lanceolata* and *P. major)* was undertaken. It seemed more desirable, since the aphids continued on apple trees out of doors until late in the summer (and all summer and into the fall on the small potted trees in the cages in the insectary shed), to continue the study of the apple forms at least as long as they remained on the trees out of doors, and whatever time was available was thus utilized. The work, undertaken in 1915, had to be repeated in 1916, owing to serious trouble encountered from mildew which attacked the young trees in the insectary shed early in the season.

KEY AND DESCRIPTIONS FOR THE SEPARATION AND DETERMINATION OF THE FIRST INSTAR STEM MOTHERS OF *APHIS MALIFOLIAE* FITCH, *POMI* DEG., *PRUNIFOLIAE* FITCH (11, P. 19-23).

KEY[1]

Cornicles long (about 1-6 to 1-10 of length of insect). Fig. 1, B.
(Base of distal segment of antennae distinctly shorter than the flagellum or unguis or distinctly less than one-half the total length of the segment.) Fig. 1, A.——————1. *Aphis malifoliae* Fitch.

Cornicles short or very short (longest about of the length of an abdominal segment). Figs. 2 and 3, B.
Base of distal segment of antennae as long or nearly as long as the unguis or equal or nearly equal to one-half the total length of the segment; cornicles about as long as an abdominal segment. Fig. 2, A & B. ——————2. *Aphis pomi* DeG., the Green Apple Aphis.

[1]The characters utilized here, as well as most of those embodied in the descriptions, can be made out by means of a hand lens or binocular microscope. The figures were drawn from balsam mounts.

Base of distal segment of antennae distinctly shorter than the unguis or less than one-half the total length of the segment; cornicles tuberculiform. Fig. 3, A & B. ————————3. *Aphis prunifoliae* Fitch (*Aphis avenae* of recent American authors), the Apple Grain Aphis.

DESCRIPTIONS

1. *A. malifoliae* Fitch (Rosy Apple Aphis)—Light to dark green, anterior portion of thorax (first two segments as a rule) usually lighter (light green may have a yellowish tint). Anterior and dorsal aspects of head, antennae, base and nearly one-half distal portion of rostrum, legs, apices of cornicles, and as a rule two transverse bands or lines at anal end of dorsum, dusky to black; the remainder of cornicles often dusky or brownish. Eyes dull black (in balsam-mounted specimens deep red). A pale median longitudinal line as a rule on dorsum of head; and often a small dusky median spot on the first thoracic segment (in good light seen to be interrupted medianly and longitudinally) and one on the side of each of the three. Caudal end of abdomen ventrally dusky sometimes. Dorsum of head and thorax and the whole of the ventral surface of the insect more or less pulverulent. Newly-hatched specimens are light green as a rule, with head, thorax, and posterior portion of abdomen at sides, occasionally, pale yellowish-green. Appendages of color of head and thorax, although the antennae and legs are more often almost colorless. Eyes deep red.

Antennae comparatively long, reaching to from end of thorax nearly to bases of cornicles; unguis about twice as long as base of distal segment; length of segments as follows: III .115-.139 mm., average .129 mm., IV (base) .054-.062 mm., (unguis) .10-.131 mm., average .119 mm.; III with a distal sensorium and base of IV with a distal group composed of one large one and several smaller ones; III and IV imbricated but III not as strongly; III sometimes shows a faint line of differentiation of segments III and IV of next stage; the whole with a few short spinelike hairs. Cornicles long, .077-.085 mm., broad, cylindrical or subcylindrical (in some balsam-mounted specimens distinctly tapering), flanged at apices, often in part weakly imbricated, and extend to about end of body and beyond. Rostrum reaches to from about metacoxae nearly to end of body (relative length varying, like that of antennae and cornicles, with the state of advancement of the insect—relatively shorter with feeding and consequent enlargement of body). Legs armed with spinelike hairs; anterior tibiae .154-.185 mm., average .173 mm.; intermediate .162-.192 mm., average .182 mm.; metatibiae .20-.246 mm., average .23 mm. Anterior tangent of head usually faintly trilobed. Eyes somewhat large. A pair of minute tubercles usually on each of last two segments (within transverse dusky lines or bands), and very often apparently a median double row of very minute tubercles or dots on remainder of dorsum, a pair on each segment. Length of body .462-.832 mm., average .61 mm.; width at widest part .246-.431 mm., average .32 mm.

2. *A. pomi* DeG. (Green Apple Aphis)—Dark green (well fed individuals may be lighter), anterior and dorsal aspects of head dusky to blackish with a pale or uncolored median longitudinal, often quite wide, band or stripe (when this latter condition obtains the dark or dusky portion appears as two elongate spots). Antennae, base of rostrum, and legs dusky; tips of femora, distal portion of tibiae, and tarsi quite often blackish. More or less of cornicles, and about 1-3 distal portion of rostrum black or blackish. Eyes black (in mounted specimens deep red). Caudal end of abdomen ventrally faintly dusky sometimes. Whole insect often slightly pruinose. Newly-hatched

specimens are bright dark green, with head and more or less of anterior portion of thorax as a rule lighter and usually with a yellowish tint; antennae, rostrum, and legs with a cast of the color of the body, and tips of femora, of tarsi and distal portions of some of the antennal segments very often darker green; femora usually distinctly yellow-green.

Antennae reach to from end of second segment to end of thorax; base and unguis of last segment equal or subequal (the inequality is slight when the specimen is not too highly magnified); length of segments as follows: III .092-.10 mm., IV (base) .046-.054 mm., (unguis) .054-.062 mm.; III with a distal sensorium and base of IV with a distal group composed of one large one and several smaller ones; III as a rule imbricated but not as strongly as IV; the whole with a few short spinelike hairs. Cornicles short, .023 mm., broad, cylindrical or very nearly so, and rounded at distal end. Rostrum reaches to or extends somewhat beyond metacoxae (varying in extent, like antennae, with feeding, as in *malifoliae*). Legs armed with spinelike hairs; anterior tibiae .146-.177 mm., average .163 mm.; intermediate .162-.208 mm., average .18 mm.; metatibiae .192-.239 mm., average .211 mm. Prothoracic and first and last pairs of abdominal lateral tubercles comparatively prominent and the last abdominal pair usually quite conspicuous—(all lose in conspicuousness as the insect body enlarges, but under higher magnification the last abdominal pair is quite easily made out in live specimens which have not fed too far, and is a very good distinguishing character). Length of body .524-.816 mm., average .676 mm.; width at widest part .277-.40 mm., average .337 mm.

3. *A. prunifoliae* Fitch (Apple-Grain Aphis)—Dull light green or dull dark green, anterior and dorsal aspects of head dusky to blackish and very often with a pale or uncolored median longitudinal line. Antennae, base of rostrum, caudal end of abdomen ventrally, and legs dusky; distal portions of femora, tibiae, and of tarsi may be still darker. Cornicles and about 1-3 distal portion of rostrum black or blackish. Eyes black (in mounted specimens deep red). Newly-hatched specimens are light green, with head and thorax (at least first two segments) still lighter or pale yellow-green; the appendages are usually with a cast of the color of the body; femora usually yellow-green.

Antennae reach about to end of thorax—"shortening up" somewhat with feeding, stoutish; flagellum or unguis about twice as long as base; length of segments: III .092-.10 mm., IV (base) .038-.046 mm., (unguis) .085-.10 mm., average .09 mm.; III with a distal sensorium and base of IV with a distal group composed of one large one and several smaller ones; IV imbricated and III as a rule in part faintly; the whole with a few spinelike hairs. Cornicles very short, tuberculiform. Rostrum reaches from somewhat beyond metacoxae nearly to end of body (relative length, like that of antennae, varying as in the other two species). Legs stoutish and armed with spinelike hairs; anterior tibiae .154-.192 mm., average .169 mm.; intermediate .169-.208 mm., average .187 mm.; metatibiae .216-.239 mm., average .224 mm. Length of body .462-.847 mm., average .641 mm.; width across widest part .262-.40 mm., average .327 mm.

THE EGG

Description.—Deep shining black, oval, .508-.539 mm. long, .231-.277 mm. wide, average .528 by .245 mm.; the greatest width does not necessarily go with the greatest length. The color of the newly laid egg varied from pale green, light green-yellow to pale yellow. This gradually turned darker green, green-yellow, then through greenish-

black to deep shining black, the entire process lasting from four to eight days, although in one instance, during the latter half of November, it took about fourteen days.

The eggs of *A. prunifoliae* measure .508-.57 by .246-.293 mm., and average .533 by .267 mm.; those of *A. pomi* .524-.616 by .216-.277 mm., with an average of .571 by .262 mm.

Location.—The eggs are laid, as a rule, in and around any roughness or place affording lodgement, and apparently, in contrast with *A. prunifoliae,* very largely on the larger branches and their twigs (9, p. 66 and 70). Those of *A. pomi* are laid principally on the terminal portions of the wood of the current season (9, p. 73).

Hatching.—The commencement and duration of the hatching period varies with the season. In 1915 the first young were observed April 7th; in 1916, March 27th. In general, hatching may be said to begin about the time the outer scales of most of the terminal buds have broken and the buds are "showing green"—about the same time as that of *A. pomi* and from about ten days to two weeks subsequent to that of *prunifoliae.* The length of the period is about two to two and one-half weeks, although the great bulk hatch in a much shorter period, and seems to be shorter than that of *prunifoliae,* and is certainly shorter than that of *pomi* (9, p. 65, 68, 72; 10, p. 29, 32, 36). In 1915 hatching was over April 19th; in 1916 about April 12th.

The mortality among the first stage stem mothers of this species, because of unfavorable food and weather conditions, is probably very small, certainly as compared with *prunifoliae,* for the reason that the commencement of hatching is practically synchronous with the opening of the buds (which provide food) and more or less favorable weather conditions (9. p. 65; 10, p. 29). (This observation holds true perhaps even more for *A. pomi* in which case hatching continues to a later date.) Owing to this better relation or adaptation, it may perhaps be said that the Rosy Aphis has been an apple pest longer than has *prunifoliae.*

STEM MOTHER

Description

First Instar.—(p. 41.)

Second Instar.—Similar to first instar except in the following respects: body color light or dull light green; variable basal portion of third segment of antennae pale; a rusty or reddish spot at base of each cornicle, and these are sometimes united between or somewhat beyond bases of cornicles across the body; transverse dark bands on last and next to last segments of dorsum of abdomen sometimes no more than spots; pulverulency as a rule somewhat more extensive. Newly moulted specimens are light green with the head and anterior two segments of the thorax lighter and usually with a yel-

lowish cast; appendages colorless but generally with a cast of the color of the body, and cornicles are often concolorous with head and anterior portion of thorax; the red or rusty spot at the bases of the cornicles may be faint and often absent; antennae, cornicles, and rostrum relatively longer than in the well fed insect.

Antennae with an additional segment, segments as follows: III .108-.139 mm., average .128 mm., IV .069-.092 mm., average .078 mm., V (base) .062-.077 mm., average .068 mm., (unguis) .131-.154 mm., average .143 mm.; IV now with distal sensorium instead of III; cornicles, .108-.131 mm., average .124 mm., generally converging towards end of body and as a rule falling short of end; rostrum reaches to between metacoxae and to somewhat beyond; posterior tibiae .277-.339 mm., average .315 mm.; lateral tubercles often apparent; anterior tangent of head as a rule more strongly trilobed; length of body .616-1.05 mm., average .804 mm., width across widest part .37-.57 mm., average .443 mm.

Third Instar.—Coloration: approaching adult. Dull light green with abdomen anterior to cornicles mottled with yellowish or yellowish green, and to unaided eye often slatish gray or bluish; pulverulency comparatively light.

Segment III of antennae may show a faint line of division of future III and IV, III usually imbricated only distally, lengths as follows: III .185-.223 mm., average .208 mm., IV .092-.108 mm., average .10 mm., V (base) .077-.085 mm., average .084 mm., (unguis) .146-.177 mm., average .159 mm.; cornicles .169-.177 mm., average .173 mm., falling short somewhat of end of body; rostrum extends about to metacoxae or to about the end of the same; posterior tibiae .383-.454 mm., average .43 mm.; length of body .97-1.39 mm., average 1.13 mm., width across widest part .616-.862 mm., average .697 mm.; otherwise similar to previous instar.

Fourth Instar.—Coloration: approaching adult quite closely.

Antennal segments as follows: III .169-.246 mm., average .197 mm., IV .108-.162 mm., average .133 mm., V .108-.146 mm., average .127 mm., VI (base) .085-.108 mm., average .096 mm., (unguis) .169-.216 mm., average .191 mm., I and II apparently not imbricated and III usually only in part; cornicles .216-.246 mm., average .228 mm., falling short somewhat of end of body; rostrum reaches to between the mesocoxae and to slightly beyond these; posterior tibiae .508-.708 mm., average .585 mm., femora apparently without sensoria-like markings; cauda, anal and subgenital plates lacking the adult differentiation; body distended with embryos; length of body 1.31-1.91 mm., average 1.53 mm., width across widest part .816-1.2 mm., average .964 mm.; otherwise similar to adult.

Fifth Stage or Adult.—Very variable—varies within limits according as it is viewed with the unaided eye or with a lens, and with the nature and angle of the light. Dull or dusky light green or gray, mottled with dull pale yellowish green (due to embryos within the body); or dull pale yellowish green with darker or gray streaks or flecks; or again entirely gray, slate gray, slate blue, purplish gray, reddish or purplish brown, and finally, old specimens may be quite dark and even blackish; head and prothorax usually dark brown to black. Antennae, with the exception generally of basal portion of III, cornicles, and base and distal portion of rostrum blackish or black. Legs black, entirely, or with exception of small basal portions of femora, but often entirely pale (dull bone-white or dull yellowish white) except for small distal portions of femora and tibiae which are black. Cauda, anal and subgenital plates black or blackish, and a black transverse band or spot, as a rule, on each of last two segments of dorsum of abdomen.

A rusty or reddish spot, generally, at the base of each cornicle, and these are often united between or somewhat beyond the bases of the cornicles across the body. Bluish white pulverulence usually heavy at ends and sides of insect and basal portions of appendages, masking parts beneath, remainder of dorsum often practically naked. One specimen, which might be called unique, approached a deep olive buff in color, lacked the reddish areas at the bases of the cornicles, and was practically free of pulverulence. Newly moulted specimens vary from dull or dusky light green to nearly blackish, with the head often lighter and the body mottled with pale or dull pale yellowish green. The appendages are colorless, although the cornicles are usually with a reddish cast due to the red liquid within. The eyes are deep red. The appendages are apt to be relatively somewhat longer.

Body generally broad, tending to globose. Antennae reach from somewhat short of end of first segment of abdomen to end of second; segments as follows: III .285-.385 mm., average .343 mm., IV .162-.231 mm., average .206 mm., V .146-.185 mm., average .162 mm., VI (base) .092-.115 mm., average .106 mm., (unguis) .185-.239 mm., average .209 mm.; imbricated—I and II may be only in part and usually on inner margin; inner margin of I generally extended ridge or claw-like; V with a distal sensorium, and ''base'' of VI with the usual group composed of one large one and several smaller ones; the whole with short spine-like hairs. Frontal tubercles on which antennae are borne small and the knob-or ridge-like extension of their inner margins help to give the anterior tangent of the head its trilobed outline. Cornicles subcylindrical and often tapering, flanged, weakly imbricated, parallel or converging caudally, and reaching to about end of body or slightly beyond; length .316-.37 mm., average .336 mm. Rostrum reaches to between and to end of mesocoxae. Posterior tibiae .747-.939 mm., average .846 mm.; intermediate and posterior femora often with faint sensoria-like markings. A pair of tubercles on each of last two segments of dorsum of abdomen, and often a pair on vertex of head (in some cases one member of the pair is missing); lateral tubercles in some cases inconspicuous, prothoracic pair usually most prominent. Cauda short, conical, setose, and with 2 pairs of long, somewhat curved, spine-like hairs; anal plate rounded or broadly conical, setose, and armed with long spine-like hairs. Length of body 1.80-2.85 mm., average 2.24 mm.; width across widest part 1.05-1.66 mm., average 1.54 mm.

Length of Nymphal Life and Instars

The duration of the nymphal period varied all the way between 24 and 12 days. The average length was about 19 days. The average duration of the instars were respectively, about 8½, 3½, 3, and 3 days, and the longest and shortest duration were, in the same order, approximately, 12¾ and 4¾, 4¾ and 2½, 4 and 2, 4 and 2 days. The first may constitute slightly more than half of the total length of the period. The periods shortened as the weather warmed—exceptions apparently being due to the condition of the food, although individuality may have contributed. The relative succulency of the food, it might be remarked, may exert a marked influence on the rate of development, as was illustrated in several instances in subsequent generations and in the sexual females, in which this factor counteracted very markedly that of temperature. Reproduction in most in-

stances began during the first 24 hours following the last moult. The longest interval was about 42 hours.

Number of Progeny and Length of Reproductive Period

The smallest number of offspring produced by one individual, out of a total of 22 which were successfully carried through from the beginning of reproduction to the end of the reproductive period, was 21; the largest was 289. The average number per female was 202.4. The largest number of young produced in one day (24 hours) by a single female was 26. The great fecundity of the stem mothers, as shown here, is indicative of the destructive capacity of the species and argues, aside from any other consideration, the importance of thorough control before the insect reaches maturity. Reproduction may continue until the very day of death, but in most cases it ceases sometime before this; the longest record was 22 days. The length of the reproductive period varied from 4 days (in the case of the individual which gave birth to only 21 young) to 41 days. The average length was about 29 days. Young were not produced every day of the reproductive period—quite often a day was skipped.

Length of Life

The length of adult life varied from 12 days (in the case again of the individual which produced only 21 young) to 48 days. The average length was about 33½ days. Seventeen individuals were carried through from hatching until death without being disturbed, and the resulting longevity varied between 41 and 78 days, with an average of about 60 days per female. The individual whose total length of life was 78 days died June 17-18, and was the last to survive. The latest that a stem mother was found in the orchard, during the same season (1916), was May 22, but it was still reproducing. Additional data regarding total length of life may be had, of course, by summing the nymphal and adult life periods.

SECOND AND SUBSEQUENT GENERATIONS

In 1915 this species continued on the apple trees in the Station orchards, in small numbers, until into the first week in August, and in 1916 until about the beginning of the fourth week, and during the latter season was absent from the apple trees only about a month (9, p. 69; 10, p. 34). In the insectary shed, however, in cages, these spring and summer forms were reared on apple throughout the summer and into fall—in 1915, until November 12, and in 1916 until October 6, when rearing was discontinued.

Ross in Ontario, in 1914 (6, p. 23), and Brittain in Nova Scotia (2, p. 16) also succeeded in doing this. Possibly—were it not for the abundance and exceeding destructiveness of insect enemies in 1916—the aphids would have lingered on the apple trees out of doors until the appearance of the first fall forms from the plantains. Winged females or migrants made their appearance, in the rearing experiments, in 1915, in the third generation (from the egg), during the first part of June, while in 1916 none developed before the fourth generation—towards the last of May. They increased in numbers, in a general way, as the season advanced, and in some of the later generations outnumbered the wingless individuals, the phenomenon varying very largely apparently with the condition of the food. In the orchards, the first migrants were found from about 10 days to two weeks earlier (9, p. 69; 10, p. 32). Do winged individuals normally develop in the second generation? Late-born undoubtedly do; for by crowding or massing, the writer succeeded in producing such in early-born specimens.

Wingless Viviparous Female

DESCRIPTION

First Instar.—Pale or light yellow, or yellowish-white (often dull), head and appendages paler or whitish (in late season head may be dark); a reddish or brownish spot at the base of each cornicle—often united between or slightly beyond the bases of the cornicles across the body and extended forward for some distance along sides of dorsum, imparting (in bright light) a pinkish cast to the whole body. The following parts sometimes dusky or black: antennae beyond III or apex of same, more or less of cornicles, distal portion of rostrum, tarsi, and apices of tibiae. Body as a rule faintly pulverulent. Eyes deep red. Newly-born individuals are almost colorless, although to the unaided eye they appear whitish, and the reddish or brownish areas in the vicinity of the cornicles are more restricted. The appendages are colorless and relatively longer.

Antennae as a rule fall short of bases of cornicles (in well advanced specimens reaching only to end of second abdominal segment); length of segments as follows: III .185-.231 mm., average .207 mm., IV (base) .062-.069 mm., (unguis) .185-.231 mm., average .21 mm.; III with a distal sensorium and "base" of IV with a distal group composed of a large one and several smaller ones; IV imbricated and III as a rule in part; III sometimes showing faint line of division of III and IV of next stage; inner margin of I often extended ridge or claw-like; the whole armed with a few short spine-like hairs. Cornicles broad, cylindrical or subcylindrical, slightly flanged, generally in part weakly imbricated, and falling short slightly of end of body; length .085-.092 mm. Rostrum reaches about to end of metacoxae. Tibiae as follows: anterior .223-.285 mm., average .245 mm.; intermediate .239-.293 mm., average .259 mm.; posterior .293-.362 mm., average .319 mm. In some instances the minute pair of tubercles on each of the last and next to the last segment of the dorsum can be made out; similarly some of the lateral tubercles may be seen, the prothoracic pair generally being more conspicuous. Antennal frontal tubercles very small. Anterior tangent of head faintly trilobed. Length of body .493-1.02 mm., average .66 mm.; width across widest part .277-.493 mm., average .348 mm.

Second Instar.—Similar to the preceding instar; the pinkish or rosy tint is usually more marked and the pulverulence is somewhat heavier.

Antennae with an additional segment, III .208-.246 mm., average .228 mm., IV .108-.115 mm., V (base) .077 mm., (unguis) .285-.308 mm., average .293 mm., IV instead of III with distal sensorium, III, IV and V imbricated, IV sometimes weakly and III with outer margin often entirely smooth, III sometimes with a faint line of division marking off future IV; cornicles .131-.146 mm., average .142 mm., and slightly curved sometimes in horizontal plane; posterior tibiae .385-.442 mm., average .413 mm.; dorsal abdominal and lateral tubercles more conspicious as a rule and the trilobation of the anterior tangent of the head generally more marked; length of body .975-1.35 mm., average 1.17 mm., width across widest part .525-.712 mm., average .622 mm.

Third Instar.—Similar to previous instar but generally duller or darker, especially in the earlier generations, and very often approaching adult. (A few individuals reared in the insectary shed in August were light green.)

Antennae with an additional segment (unlike First or Stem Mother Generation in which the additional final segment does not appear—although it may be indicated—until after the third moult) and V instead of IV with distal sensorium, length of segments: III .169-.208 mm., average .189 mm., IV .162-.20 mm., average .183 mm., V .131-.154 mm., average .146 mm., VI (base) .085-.092 mm., (unguis) .316-.385 mm., average .354 mm.; cornicles .192-.208 mm., average .202 mm., and usually slightly curved in one or both planes; rostrum extends about to metacoxae and to their ends; posterior tibiae .50-.624 mm., average .571 mm.; length of body 1.09-1.61 mm., average 1.45 mm., width across widest part .619-.937 mm., average .811 mm.; otherwise similar to previous instar.

Fourth Instar.—Similar to previous instar but may approach adult quite closely. (A few specimens reared in the insectary shed in August were light green, as in the case of the third instar specimens, but like the latter were not typical—certainly not for the time of season.)

Antennal segments: III .293-.339 mm., average .311 mm., IV .216-.277 mm., average .239 mm., V .169-.20 mm., average .183 mm., VI (base) .10-.108 mm., (unguis) .385-.439 mm., average .413 mm., I and II apparently not at all and III with only inner margin imbricated; cornicles sometimes practically cylindrical, and usually weakly imbricated, length .277-.285 mm.; rostrum reaches about to metacoxae; posterior tibiae .678-.793 mm., average .716 mm.; cauda, anal and subgenital plates not differentiated as in adult; length of body 1.65-1.99 mm., average 1.74 mm., width across widest part .937-1.09 mm., average .975 mm.; otherwise similar to adult.

Fifth Instar or Adult.—Very variable in color, even more so than adult stem mother, due, presumably, to the longer season during which it occurs.

Dull light—or dull yellowish green, or dull yellowish, marked with dull, dusky or yellowish green; again, gray, bluish, purplish, pinkish, dull yellowish, earth brown, grayish brown, and reddish or rosy brown (the gray, bluish, and purplish forms are found principally in the earlier generations and are apparently due largely to the heavier pulverulence), head and prothorax very often dusky or black; red or reddish spots at bases of cornicles usually united across body. The following parts dusky to black: antennae except a variable basal portion which may extend to the distal segment (first two segments are often also dusky); entire or distal portions of cornicles; distal portion and base, sometimes, of rostrum; tarsi; apical portions of tibiae and of femora usually

(posterior and intermediate more often and more extensively); and often the posterior and intermediate coxae, cauda, anal and subgenital plates and a transverse band or spot on each of last two segments of dorsum. The remainder of the antennae, cornicles, rostrum, and legs are dull yellowish-white, although that of the cornicles may partake of the color of the body. Pulverulency heavy in earlier and very light in later generations and invariably lighter about in middle of dorsum. Eyes apparently dull black. The more extensive black markings occur in the earlier generations. Newly moulted specimens are lighter or brighter in color, and the appendages are colorless and relatively somewhat longer.

Antennae reach about to bases of cornicles; segments: III .431-.577 mm., average .483 mm., IV .293-.462 mm., average .36 mm., V .185-.285 mm., average .238 mm., VI (base) .10-.139 mm., average .114 mm., (unguis) .416-.585 mm., average .48 mm.; imbricated—I and II usually only in part and on inner margin, and outer margin of III weakly and sometimes entirely smooth; inner margin of I usually extended ridge or claw-like; V with a distal sensorium and ''base'' of VI with usual group; the whole armed with short spine-like hairs. Cornicles subcylindrical, sometimes tapering throughout, flanged, imbricated, parallel or slightly converging towards end of body, slightly curved usually in one or both planes, and falling short somewhat of end of body; length .339-.416 mm., average .37 mm. Rostrum reaches to between mesocoxae but may extend nearly to metacoxae. Posterior tibiae .878-1.25 mm., average 1.05 mm. A pair of tubercles, except in rare instances, on each of last two segments of dorsum, and a pair of tubercle-like structures sometimes on vertex of head; prothoracic pair most prominent of lateral tubercles. Cauda short, conical, setose, and armed with two and sometimes three pairs of long and generally curved spine-like hairs. Anal plate rounded or broadly conical, setose, and with long spine-like hairs. Frontal tubercles on which antennae are borne small and inner margins generally extended ridge or claw-like. Anterior tangent of head trilobed. Length of body 1.39-2.51 mm., average 2.14 mm.; width across widest part .862-1.72 mm., average 1.37 mm.

Winged Viviparous Female (Migrant)

DESCRIPTION

First and *Second Instars* as in wingless viviparous female.

Third Instar.—Flesh to carrot red; abdomen usually wholly or in part pale yellowish or pale yellowish green (often dull); indicated future wing pads as a rule dull whitish; head dirty yellowish white to dusky; a brownish spot at base of each cornicle and usually united between or somewhat beyond bases of cornicles across body. Antennae dull yellowish white and shading into blackish or black distally, but often entirely dark. Rostrum colorless to yellowish-white, apex black. Cornicles colorless to brownish shading into dusky and black distally. Legs from almost colorless to dull yellowish-white; apices of tibiae often dusky; tarsi black or blackish. Caudal end of abdomen ventrally often dusky. Eyes apparently black (under magnification and in good light deep red). More or less pulverulent, dorsum behind thorax generally lightly or naked. The red body color is heightened when specimens are on green leaves and when they are massed together, as in colonies.

Antennae reach to bases of cornicles or to slightly beyond; length of segments: III .20-.223 mm., average .212 mm., IV .162-.20 mm., average .18 mm., V .139-.146 mm., VI (base) .085-.10 mm., average .091 mm., (unguis) .323-.385 mm., average .353 mm.; segments beyond II imbricated, III generally and IV sometimes weakly and only on

inner margin; V with distal sensorium and base of VI with usual group; inner margin of I generally extended ridge or claw-like; the whole with short spine-like hairs. Cornicles cylindrical or subcylindrical, distinctly tapering sometimes, flanged, often slightly curved in one or both planes, converging more or less caudally as a rule, generally in part weakly imbricated, and extending about to end of body or somewhat beyond; length .169-.208 mm., average .194 mm. Rostrum reaches to metacoxae and to between them. Posterior tibiae .547-.624 mm., average .588 mm. A pair of tubercles on each of last two segments of dorsum, the posterior pair often more conspicuous; lateral tubercles often minute, prothoracic pair generally more prominent. Anterior tangent of head trilobed; antennal frontal tubercles very small. Length of body 1.31-1.76 mm., average 1.46 mm.; width across widest part .675-.90 mm., average .756 mm.

Fourth Instar (so-called pupa).—Salmon to carrot red (sometimes dull) interrupted more or less with yellowish (dorsum of abdomen anterior to cornicles generally yellowish red), often bluish or purplish, and rarely dull green mottled with light or yellowish green, head dull yellowish-white to dusky and prothorax sometimes likewise; wing pads yellowish-white, with more or less of distal portions generally dusky; antennae often entirely dark except for basal portion of III; cornicles dull pale yellowish or dull yellowish-white, black or blackish distally—often as much as ¼; legs yellowish-white, distal portions of tibiae and often of femora dusky, tarsi black or blackish; pulverulence generally heavier on ventral surface and at ends of dorsum; otherwise similar to previous instar. Newly moulted specimens are lighter or brighter in color, with the appendages colorless (cornicles usually stained brown in part by liquid within) and relatively somewhat longer. The eyes are deep red.

Antennae may not quite reach to bases of cornicles, segments: III .331-.447 mm., average .39 mm., IV .239-.323 mm., average .275 mm., V .177-.223 mm., average .198 mm., VI (base) .10-.123 mm., average .108 mm., (unguis) .354-.524 mm., average .447 mm.; cornicles subcylindrical, falling short of end of body but occasionally reaching to end, length .231-.277 mm., average .267 mm.; rostrum to mesocoxae and to somewhat beyond these; posterior tibiae .75-.862 mm., average .821 mm.; vertex of head apparently sometimes with a pair of minute tubercles or papillae; length of body 1.95-2.29 mm., average 2.16 mm., width across widest part .937-1.24 mm., average 1.09 mm.; otherwise similar to previous instar.

Fifth Instar or Adult.—Head and thorax black, generally shining black, less chitinized parts greenish or yellowish red to brownish; abdomen dull greenish yellow, dull yellowish, or brownish, venter marked with red or reddish and generally slightly pulverulent, dorsum with a large, often quadrate, spot or patch of variable size about in middle (very often extending transversely over the whole of the dorsum, and rarely extending forward nearly to thorax, more rarely broken up and consisting of a number of small spots) and a black caudal area which is generally continued along the margins to the bases of the cornicles (the two patches are sometimes fused, and very often the latter is replaced by two transverse black bands); 3 distinct black spots on each side of abdomen anterior to bases of cornicles. Antennae black. Rostrum greenish through yellowish to brownish yellow, with base and apical portion black or marked with black. Cornicles black or blackish—distal portions sometimes brown. Coxae black or blackish (anterior ones generally only dusky); distal portions of anterior femora (generally ½) and ¾ to more of intermediate and posterior black, basal portions dull yellowish white or brownish yellow; tibiae dull yellowish-white to brownish, distal portions and tarsi black. Cauda,

anal and subgenital plates black or blackish, last generally with a paler posterior margin. Eyes dull deep red or blackish brown or dull black. Wings hyaline; bases and basal portions of costa and subcosta (sometimes the whole) greenish yellow or yellowish; stigma and veins dusky or brown, basal portions of latter usually paler; tegulae generally light green.

Antennae long, reaching about to end of body or slightly beyond; III and IV thickly studded with sensoria; length of segments as follows: III .508-.654 mm., average .588 mm., IV .354-.431 mm., average .395 mm., V .246-.308 mm., average .274 mm., VI (base) .115-.139 mm., average .126 mm., (unguis) .50-.693 mm., average .579 mm.; III with 48-66 sensoria (average 56), IV with 21-31 (average 25), V with 3-9 (average 6); imbrication of III and IV obscured by sensoria, outer margin of I not at all or weakly imbricated, likewise inner margin of II more strongly than outer; usual sensorium at distal end of V and group at distal end of "base" of VI; inner margin of I generally extended ridge or claw-like; the whole armed with short spine-like hairs. Rostrum reaches about to mesocoxae and to slightly beyond them. Cornicles cylindrical or subcylindrical, weakly imbricated, generally slightly curved in one or both planes, flanged, parallel or slightly converging towards end of body, and reaching to or falling somewhat short of end; length .262-.339 mm., average .316 mm. Legs comparatively long; posterior tibiae 1.05-1.35 mm., average 1.24 mm. A pair of tubercles usually on each of last two segments of dorsum of abdomen; lateral abdominal tubercles not very conspicuous, prothoracic pair more prominent; occasionally a pair on vertex of head. Cauda short, conical, setose, armed with two and sometimes three pairs of long and somewhat curved spine-like hairs; anal plate much broader than cauda, rounded or broadly conical, setose, and with long spine-like hairs. Antennae borne on small frontal tubercles the inner margins of which are extended ridge or claw-like, giving the anterior tangent of the head a very distinct and usually sharply trilobed outline. Wing venation usually normal; radius strongly curved; apical fork of medius generally somewhat nearer to apex of wing than to the basal fork; veins delicate to moderately heavy. Length of body 1.57-2.29 mm., average 1.96 mm.; wing expanse 5.21-6.67 mm., average 5.94 mm.

Length of Nymphal Life and Instars

The length of the nymphal period varied from 7 days, in the case of an individual of the Tenth Generation, to 16½ days, in the case of one belonging to the Second Generation. The average length was about 9¾ days. The instars varied as follows: first, from 1¾ to 6¼ days; second, 1½ to 3; third, 1½ to 5¼; the fourth, from 2 to 4. The average duration of each, following the same order, was approximately 2¾, 2, 2, and 2½ days. The first was distinctly the longest during the earlier part of the season—up to about the middle of May, with the fourth somewhat longer than either of the other two, subsequently they became more equalized. Two individuals apparently moulted five times, two skins being found in each case between the true second and third stages. Reproduction begins during the first 24 hours following the final moult, but it may not begin until during the following 24. In one instance, it is definitely known to have begun within a few hours after the adult stage was reached. Winged females, under the same conditions, develop as a rule somewhat more

slowly. In these the duration of the nymphal period varied from 8 to 16 days, the average length being about 11.5 days. Data bearing on the duration of the individual instars in the development of the latter form is not available, owing to their failure to develop in this series of the experiments.

Number of Progeny and Length of Reproductive Period

The average number of young per female (wingless) produced by 32 individuals which were followed throughout their reproductive period was 114.43. The largest number, 196, was produced by one of the Second Generation (from the egg), the smallest, 27, by one of the Fifth Generation. Roughly speaking, there was a gradual fallng off with the advancement of the season. The length of the reproductive period varied from 6 days, in the case of the female which produced only 27 young, to 33½ days, in the case of one belonging to the Second Generation. The average length of the period was about 23 days; and it was generally longer in the earlier generations. As in the case of the Stem Mothers, young were not necessarily produced every day; in one instance, in the case of a female of the Eighth Generation, at the end of July and beginning of August, 6 consecutive days were skipped, but this was towards the end of the period. Females generally lived for some days after ceasing reproduction; one (Fourth Generation) lived for 21 days thereafter. The largest number of young produced in one day by a single female was 20, and by one of the Second Generation.

Length of Life

The length of the adult life varied from 7½ days, in the case of a female belonging to the Fifth Generation, to 43 days, in the case of one of the Second Generation. The average length was about 29½ days. The resulting longevity in the case of the individuals which were followed throughout life, from birth to death, without being disturbed, varied from 17 days to 55½ days, with an average of about 40 days. In a general way, longer life was characteristic of the earlier generations. Additional data bearing on the total length of life may be obtained by summing the nymphal and adult life periods.

NUMBER OF GENERATIONS

In 1915 a maximum number of 12 generations (from the egg) were reared up to about the time the aphids completely disappeared from the

apple trees out of doors (about the end of the first week in August) and a maximum of 17 to about the time the species commenced to return to the apple from the plantains (first days of October). Similarly, there were a maximum number of 14 (beginning of fourth week in August) and 17 generations (beginning of last week in September) in 1916, with theoretical minima of 4 and 5, respectively. Both seasons a maximum of 7 were reared between hatching and about the time the aphids became rare on the bearing trees—the latter part of June.

FALL FORMS

This species begins its return to the apple from the narrow and broad-leaved plantains *(Plantago lanceolata* and *P. major)*, its alternate host plants, as already indicated, towards the last of September or beginning of October; the first winged viviparous females or return migrants were found October 2, in 1915, and September 24, in 1916 (9, p. 69; 10, p. 34). The apple-grain aphis (*A. prunifoliae* Fitch) begins to return about the same time. The winged females precede the males; in 1915 the first specimens of the latter were observed October 8th, in 1916 October 9th. The first males seem to arrive before the first oviparous females reach maturity. They feed on the underside of the leaves, which are not curled at this season, often beside the egg-laying females, until the time for mating arrives. In 1916, the species was absent from the apple trees in the Station orchards only about a month.

Winged Viviparous Female (Return Migrant)

DESCRIPTION

Fifth Instar or Adult.—Similar to the Spring or Summer Migrant. The color of the abdomen is very variable—greenish, brownish green, blackish green, reddish green, green marked with red, reddish, reddish black, brownish-black, greenish-black, blackish, blackish brown, reddish brown, and brown, the dorsum is shining black (broken up into spots sometimes), reddish black, or reddish brown, entirely, or with the exception of a narrow anterior portion, or it may be with a single large black patch about in the middle and a transverse line or stripe at the caudal end which in turn may connect on each side with a black spot at the base of each cornicle, or again, more rarely, it may be of the Spring or Summer Migrant type—with a large spot or patch about in the middle and with a black caudal area which is continued along the margins to the cornicles; the less chitinized parts of the head and thorax may be reddish; the cornicles may be entirely brown; the light or pale portions of the legs are brownish or brownish yellow; the cauda, anal and subgenital plates may be in part or entirely brownish; and the apical portions of the anterior wings may be faintly dusky.

Antennae generally reach beyond end of body, segments as follows: III .60-.739 mm., average .658 mm., IV .362-.508 mm., average .425 mm., V .216-.323 mm., average .277 mm., VI (base) .115-.139 mm., average .13 mm., (unguis) .477-.662 mm., average .562 mm., III with 47-67 sensoria (average 58), IV with 17-35 (average 23.7), V with 3-10 (average 5.7); rostrum extends about to mesocoxae and to between them; cornicles .285-.37 mm., average .333 mm., and may reach to beyond end of body; posterior tibiae 1.12-1.39 mm., average 1.26 mm.; dorsal tubercles on last two segments of abdomen apparently absent; abdominal lateral tubercles and prothoracic pair generally minute; apparently no tubercles on vertex of head; wing veins generally moderately heavy, apical fork of medius generally about half way between apex of wing and basal fork or nearer the latter; length of body 1.61-2.17 mm., average 1.92 mm.; wing expanse 5.74-7.35 mm., average 6.66 mm.

Male

Fifth Instar or Adult.—Similar to the Fall or Return Migrant. The color of the abdomen, as in the females, is very variable—light green, green, reddish, red, reddish brown, brown, brownish black, and often in part green and in part red or brown; the dorsum is of the following types: (1) reddish black, brownish black, or black, entirely, or (2) except narrow anterior or lateral margins, (3) the black is broken up and occurs as spots or transverse bands, (4) with a large central black spot or patch, or an elongate median spot extending to the cornicles, and one or two transverse lines or bands caudad.

Slenderer than return migrant; antennae reach beyond end of body, segments as follows: III .539-.693 mm., average .616 mm., IV .293-.477 mm., average .381 mm., V .216-.323 mm., average .272 mm., VI (base) .10-.139 mm., average .116 mm., (unguis) .454-.608 mm., average .535 mm., III with 48-82 sensoria (average 62), IV with 18-31 (average 24.7), V with 6-11 (average 8.2); cornicles .254-.323 mm., average .285 mm.; posterior tibiae .937-1.22 mm., average 1.11 mm.; anal plate broad, and usually broadly rounded; medius more like in the spring and summer migrant; length of body 1.5-2.17 mm., average 1.7 mm.; wing expanse 5.1-6.86 mm., average 5.92 mm.

The nymphal stages of the return migrant and male occur exclusively on the alternate host plants.

The winged females and males may persist on the apple out of doors until about the middle of December, and reproduction on the part of the former continues until about the middle of November (9, p. 70; 10, p. 34). Similarly, wingless viviparous females may continue on plantains out of doors until early in December, at least on the broad-leaved plantain *(P. major)* on which they are relatively more numerous during the latter part of the fall and on which they seem to persist longest.

Oviparous Female

The egg-laying females begin to be deposited on the apple by the winged viviparous females about as soon as they arrive (9, p. 70; 10, p. 34), and adults may be found during the second week of October.

Oviposition commences about the middle of October and continues until within a short time of the death of the females. The oviparous females persist somewhat longer than the winged females and males.

DESCRIPTION

First Instar.—Pale greenish yellow (the greenish cast is less marked when the insect is removed from the green leaf) to dull pale yellow, head as a rule paler and shiny; a brownish yellow spot generally at the base of each cornicle and these are often continued faintly across the body. Antennae colorless or nearly so, darkish from and beyond apex of III. Cornicles colorless or faintly dusky, and generally tipped with black. Rostrum colorless, apex black. Legs colorless; tarsi sometimes dusky and apices blackish. Sutures of head and thorax and ventral surface of body often faintly pulverulent. Eyes deep blood red. The colorless parts of the appendages are often with a cast of the color of the body. Newly-born individuals appear white or whitish to the unaided eye and under magnification are almost colorless. The appendages are colorless and relatively longer.

Antennae fall somewhat short of bases of cornicles; imbricated beyond II or distal half of III, but rather weakly up to unguis—outer margin of III sometimes entirely smooth; inner margin of I sometimes extended ridge or claw-like; usual distal sensorium on III and group on ''base'' of IV; the whole armed with a few short spine-like hairs; measurements: III .123-.154 mm., average .141 mm., IV (base) .054 mm., (unguis) .169-.20 mm., average .182 mm. Rostrum extends to between and to end of metacoxae. Cornicles cylindrical (in mounted specimens generally subcylindrical), straight, parallel or converging, slightly flanged, weakly imbricated as a rule, and falling short somewhat of end of body; length .069-.085 mm., average .076 mm. Tibiae: anterior .139-.177 mm., average .162 mm.; intermediate .154-.185 mm., average .174 mm.; posterior .20-.246 mm., average .222 mm.; distal half of posterior generally stoutish. Frontal tubercles very small and anterior tangent of head faintly trilobed. Length of body .493-.676 mm., average .575 mm.; width across widest part .246-.323 mm., average .279 mm.

Second Instar.—Similar to first instar. Color usually more pronounced—to unaided eye straw-white or yellowish white, and the distal portions of the tibiae may be dusky; eyes blackish in dull light.

Antennae with an extra segment, and IV instead of III with distal sensorium, segments: III .108-.123 mm., average .121 mm., IV .069 mm., V (base) .054-.062 mm., (unguis) .177-.20 mm., average .19 mm.; rostrum extends to from slightly beyond mesocoxae to between metacoxae; cornicles .085-.10 mm., average .091 mm.; posterior tibiae .231-.269 mm., average .255 mm., usually stoutish; length of body .601-.893 mm., average .708 mm., width across widest part .308-.447 mm., average .371 mm.

Third Instar.—Pale yellow, often with a greenish cast or reflection; antennae dusky to blackish beyond III or apex of same; basal portions of cornicles nearly colorless or concolorous with body, dusky beyond, and tipped with black; rostrum nearly colorless or concolorous with under surface of body, apex black. Otherwise similar to previous instar.

Antennae may reach to bases of cornicles, segments: III .162-.177 mm., average .169 mm., IV .085 mm., V (base) .062-.069 mm., (unguis) .208-.231 mm., average .22 mm.; rostrum from about end of mesocoxae to metacoxae; cornicles cylindrical or subcylindrical, length .108-.123 mm., average .12 mm.; posterior tibiae .308-.331 mm., average .315 mm.; length of body .739-1.11 mm., average .867 mm., width across widest part .40-.585 mm., average .464 mm. Otherwise similar to previous instar.

Fourth Instar.—Pale greenish yellow or pale yellow (to the unaided eye may approximate to straw color); antennae colorless or nearly so, variable distal portion dusky and black. Otherwise similar to adult.

Antennae may reach to bases of cornicles, imbricated beyond II or III—in general weakly up to VI, III .139-.169 mm., average .152 mm., IV .115-.123 mm., V .10-.115 mm., average .109 mm., VI (base) .069-.085 mm., average .076 mm., (unguis) .20-.269 mm., average .244 mm.; rostrum from about end of mesocoxae nearly to metacoxae; cornicles parallel or convergent towards end of body, length .146-.169 mm., average .155 mm.; metatibiae .385-.431 mm., average .409 mm.; cauda, anal and subgenital plates lacking the adult differentiation; length of body 1.01-1.35 mm., average 1.13 mm., width across widest part .525-.75 mm., average .615 mm. Otherwise similar to adult.

Fifth Instar or Adult.—Pale or light yellow (very often with a greenish cast or reflection), dorsum of abdomen anterior to cornicles usually richer yellow and quite often amber—or golden yellow (imparted apparently by the maturing eggs), older specimens very often dull or olivaceous; head paler and shiny but generally growing duller or dusky and blackish with age; a brownish spot as a rule at the base of each cornicle and often united between or immediately beyond the bases of the cornicles across the body. Antennae colorless or nearly so, more or less of distal portion dusky to black; often entirely dark. Cornicles colorless or concolorous with body, variable distal portion dusky, extreme apex black; not infrequently entirely dusky, and sometimes entirely blackish. Rostrum colorless or concolorous with head and body, apical portion black. Legs colorless or concolorous with body, apical portions of tibiae and of tarsi dusky to black—but the extent of the dark over color is quite variable and the entire legs may be dark. Cauda, anal and subgenital plates often darkish. Eyes deep red—in dull light and when not too highly magnified, black. More or less of undersurface and sides of body slightly pulverulent. Newly moulted specimens are lighter and brighter in color, with colorless and relatively somewhat longer appendages.

Antennae slender, generally falling short somewhat of bases of cornicles; imbricated beyond II, but inner margins of I and II very often also and outer margin of III very often smooth, in general weak to V or VI; V with a distal sensorium and "base" of VI with usual distal group composed of one large one and several smaller ones; inner margin of I often extended ridge or knob-like; the whole armed with short spine-like hairs; length of segments: III .192-.246 mm., average .217 mm., IV .123-.169 mm., average .14 mm., V .115-.154 mm., average .126 mm., VI (base) .077-.085 mm., (unguis) .239-.323 mm., average .278 mm. Rostrum reaches to between mesocoxae and to metacoxae. Cornicles cylindrical or subcylindrical, generally slightly curved in one or both planes, flanged, weakly imbricated, converging or diverging towards end of body and generally falling short somewhat of end; length .162-.20 mm., average .182 mm. Posterior tibiae .431-.57 mm., average .469 mm., stout, and with numerous sensoria-like markings. Cauda short, conical, setose, and with 2 pairs of long somewhat curved spine-like hairs. Anal plate broadly conical, setose, and armed with a number of long spine-like hairs. Frontal tubercles on which antennae are borne small, inner margins more

extensive and give the anterior tangent of the head a trilobed outline with the lateral lobes quite prominent. Length of body 1.05-1.7 mm., average 1.28 mm.; width across widest part .524-.832 mm., average .721 mm.

LENGTH OF NYMPHAL LIFE AND INSTARS

The longest and shortest duration of the nymphal period was 37½ and 12 days, respectively. The average length of the period was about 23 days; and if allowance is made for a few exceptions which were apparently due to unfavorable food conditions, it may be said to have progressively lengthened with the season. The instars varied as follows: first, from 2¼ to 11½; second, from 2½ to 13; third, from 2¾ to 11; fourth, from 4¾ to 15½ days. The average length of each, in the same order, was about 4½, 6, 7, and 8½ days. About 7 days was the shortest time between the last moult and the beginning of oviposition, and about 13 the longest. The average was about 10½.

NUMBER OF EGGS LAID AND LENGTH OF OVIPOSITION

The highest number of eggs laid by a single female was 7. Under more favorable conditions, as many as 8 would probably have been laid, as an additional egg was dissected out of the dead body of one of the individuals. The average number laid per female was close to 6. The lengths of the intervals between the successive eggs varied, respectively, from ½ to 4½, ½ to 3½, 1 to 5, 4 to 12, 5½ to 11, and 7½ to 14 days. The average length of each, in the same order, was about 2, 2, 3½, 7½, 8, and 10 days. The above females, it might be added, were given males from time to time throughout the oviposition period, and mating was observed in a number of instances. The length of the oviposition period varied from 1 to 44 days, and the average length was 24 days. Females may live for nearly 2 weeks after they have finished ovipositing.

ADULT LIFE

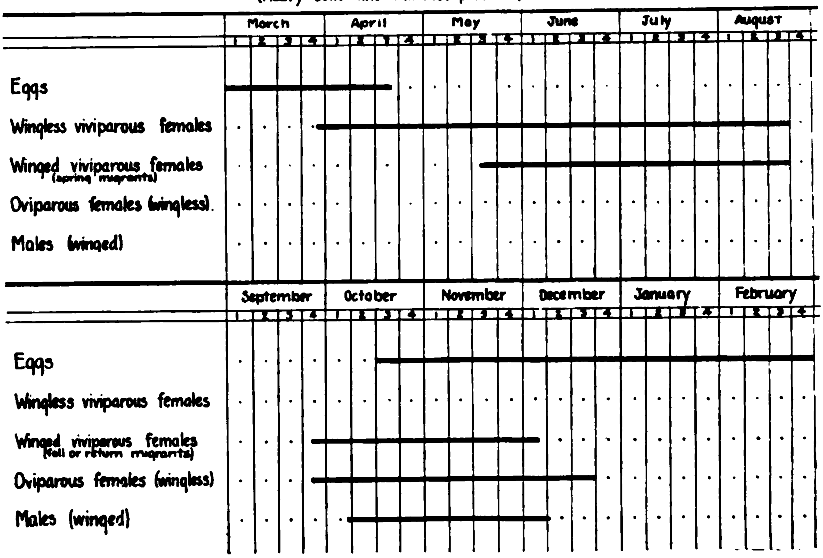
The shortest duration of this period was 9½ days; the longest 67. The average length was about 36 days.

MATING

Mating may take place on any part of the tree; generally, however, and especially at the height of the egg-laying season, it occurs on the larger branches and their twigs, where the eggs seem to be largely laid, and where the males seek out the females. As regards the length of time the sexes will remain united, two records are available, as follows: (1) coupled at 2:18 p. m. (Oct. 20, 1916), disconnected between 2:25 and 2:30 p. m.; (2) coupled at 10:38 a. m. (Oct. 23, 1916), disconnected at 11:00 a. m. A male

CHART SHOWING OCCURRENCE OR ABSENCE OF THE VARIOUS FORMS OF THE ROSY APHIS (*APHIS MALIFOLIAE* FITCH) ON APPLE TREES AT BLACKSBURG, VA.[1]

(Heavy solid line indicates presence; dotted line absence.)



may unite with more than one female, and, presumably, a female will accept more than one male. The sexes of this species will also unite with those of *A. prunifoliae*.

ENEMIES

Insect enemies are exceedingly helpful in checking this species on the apple. The principal of these are hymenopterous parasites and coccinellid larva. The latter are especially destructive—owing to their occurrence in largest numbers at the time the aphids are most abundant, and because of their great activity and voracity. They are aided, again, by the massing or crowding habit of the aphids (9, p. 69). As many as 3 well-grown individuals have been found working simultaneously in a curled-leaf colony, and colonies are literally wiped out by them.

Hymenopterous Parasites[1]

The list of parasites bred by the writer, and kindly identified by Messrs. Crawford, Gahan, and Girault, of the U. S. National Museum, together with the records of the periods during which they were bred, follows:

Lysiphlebus testaceipes Cress. May 16-July 19; Cloverdale, July 17-20.

Ceraphron sp. May 29-July 25.

[1]Reproduced from Eleventh Report of State Entomologist of Virginia (10, p. 32).

[1]Bred from wingless viviparous females on the apple, at Blacksburg, unless otherwise indicated.

Asaphes americana Girault. June 12-July 29.

Propachyneuronia siphonophorae (Ashm.). July 5-August 16.

Pachyneuron spp. July 10-August 7; September 19 (from a specimen on a small tree in the insectary shed).

P. virginicum Girault. August 3-5.

Aphidius phorodontis Ashm. July 12; October 27-31 (from specimens on *Plantago lanceolata).*

Lygocerus stegmatus Say. July 17-19.

Tetrastichodes detrimentosus Gahan. July 17-August 1.

Predaceous Enemies

COCCINNELLIDAE

The following were identified by the writer in their adult stage:

Adalia bipunctata L. April 20-July 3. It occurred practically throughout the season and seems to have been the most common species.

Cycloneda munda Say. April 22-29.

Hippodamia convergens Guer. April 22-May 8.

Coccinella novemnotata Hbst. April 24-June 12.

Psyllobora 20-maculata Say. April 25.

Anatis 15-punctata Oliv. April 25-May 21.

Megilla fuscilabris Muls. April 26-27.

Chilocorus bivulnerus Muls. May 18.

Scymnus collaris Muls. July 19.

DIPTEROUS

Only one species was reared, namely, *Leucopis griseola* Fallen.[1] This appeared to be the most common species. The emergence records cover the period between June 16 and August 9, and includes material from Cloverdale, Va.

NEUROPTEROUS

Chrysopa larvæ were observed preying upon oviparous females during October and November.

MISCELLANEOUS

Adult Elateridae and spiders were found a number of times in the curled leaf colonies (or within the leaves where colonies had existed), but the writer has no positive evidence of their feeding on the aphids. At any rate, their importance as enemies, at such time, cannot be very great, as they do not seem to appear in these situations until the season is well advanced and

[1]Identified by the late Frederick Knab of the U. S. Bureau of Entomology.

the aphids are largely gone from the trees. Spiders are perhaps of greater importance in fall when rather large numbers of the winged aphids are caught in the webs spun among the branches and twigs of the trees.

SPRAYING EXPERIMENTS

In 1916 experiments were conducted which were designed, first, to test the efficacy of the recommendations and practice (then in vogue) for the control of apple aphids,[1] and, secondly, to discover the possible relations between the aphids and fire-blight *(Bacillus amylovorus)* which was widely prevalent and very destructive the year before. The major portion of this work was carried on in the commercial orchard of Mr. J. H. Stephens, in Cambria, about five miles distant from Blacksburg, and Mr. Stephens kindly co-operated further by furnishing spraying machinery and help. The orchard consisted of the York Imperial and Ben Davis varieties, and the trees were about 14 years old. The rows, as they were sprayed, consisted of about 25 trees each and of alternate trees of the two varieties. Here a block of 13 rows was selected, and on April 4, Rows Nos. 2, 4, 6, and 8 were given an application of "Black Leaf 40," at the rate of ¾ of a pint in 100 gallons of water, with the addition of 4 pounds of potash fish oil soap to each 100 gallons—each tree receiving on an average about 4 gallons of the mixture. Rows Nos. 1, 3, 5, 7, and 9 were left as checks. At this time all the buds were showing green— many of the Ben Davis, the farther advanced of the two varieties, had already begun to unfold, and the aphids (*prunifoliae* at least) had apparently all hatched. The trees were heavily infested with *prunifoliae,* but *malifoliae* was scarce, and the infestation was somewhat heavier at the end of the orchard which was situated on a slight rise. The trees had received the customary dormant San Jose Scale treatment, about ten days previous.

The first examination was made April 12, and showed that the spraying was very effective—but few aphids were apparent on the sprayed trees.

A second examination was made April 20, and as on the day of the previous examination, the sprayed trees showed but few aphids and some were apparently clean. Here and there, however, a heavily infested bud was found, but these were terminals on the extreme outside of the trees which had evidently been missed in spraying. The check rows, on the other hand, were rather heavily infested, and the numbers were rapidly being augmented by the reproduction of the Stem Mothers. All the flower clusters were now "showing pink."

[1]These, in the main, consisted of (1) one spraying with Nicotine Sulfate (40%), at the rate of ¾ of a pint in 100 gallons of water, with the addition of 3-5 pounds of soap to each 100 gallons of the mixture, at the time of the opening of the buds—"latter showing green"; (2) one spraying with Nicotine, at the same rate, in the dilute lime sulfur—scab treatment—at the time the blossom buds "showed pink"; (3) both treatments.

On the same day Rows Nos. 6, 8, 10, and 12 were given an application of lime sulfur (27° B.; 1 to 20) plus ¾ of a pint of "Black Leaf 40" in each 100 gallons, each tree receiving on an average about 7¾ gallons of the mixture. Rows 11 and 13 were left as additional checks. On the same day, it should be noted, at least some individuals of *malifoliae* were already within curled leaves. About 3:30 p. m., the aphids on the first sprayed trees were already dying; the day was bright and fairly warm.

The next examination was made April 28th, and the observations were as follows: Rows 2 and 4, which were sprayed only once—April 4, with nicotine and soap—quite clean. Rows 6 and 8, which were sprayed twice—April 4, with nicotine and soap, and April 20, with lime sulfur and nicotine—also clean, of course, superficially at least not cleaner than Rows 2 and 4. Rows 10 and 12, which were sprayed only with lime sulfur and nicotine on April 20, not as clean as the above four rows, but not as badly infested as the checks, occupying a sort of intermediate position. The check rows were rather unevenly infested, but for the most part badly, and in places—particularly on the higher ground—very badly.

On May 18, the date of the next examination, *prunifoliae* was about gone from the trees, and the presence of *malifoliae* was more noticeable. However, the infestation was quite light. The check rows showed from one to several clusters of colonies on the part of the majority of its trees; Rows Nos. 6 and 8 disclosed one or two clusters on isolated trees; and Rows 2 and 4 were about as clean. Nos. 10 and 12 were but slightly cleaner than the adjacent checks.

The final examination was made after the apples had matured, September 11 and 16, and had for its object the comparison of the abundance and quality of the fruit on the untreated and differently treated trees. In both regards no difference could be noticed, if about three-fourths (up to about rise in the ground) of Row No. 8 is excepted, the yield here being about 50% lighter. Row No. 8, it should be recalled, was among the freest of aphids. The yield the orchard over was good. Observations on the keeping qualities of the fruit could not be made.

CONCLUSIONS

Nothing can be said regarding relations between the aphids and fire-blight, owing to the failure of the latter to develop. Similarly, very little can be said regarding the value of the spraying measures as means for the control of *malifoliae*. Definite conclusions, however, can be drawn with reference to *prunifoliae*, which was not only abundant but was practically alone on the trees and these, subject to the qualification that they are based on one season's operations, are as follows:

1. Good control of *prunifoliae* may be obtained by one thorough application of Nicotine Sulfate (40%) in water (1 to about 1000) and soap (4

lbs. to 100 gals.) about the time the compact "green-showing" buds begin to unfold, at which time the aphids of this species are all hatched.

2. There seems to be little or no advantage in a later application of Nicotine Sulfate (1 to about 1000) in lime sulfur (1 to 20) at the time the flower clusters show pink, if the early application is well timed and thorough.

3. One spraying consisting of an application of Nicotine Sulfate (1 to about 1000) in lime sulfur (1 to 20) at the time the flower buds show pink is apparently of little or no benefit. (See also Table II, p. 63).

4. *Prunifoliae* seems not to affect either the yield or quality of the fruit, even when abundant, and it may be regarded, therefore, under usual conditions, as being of but slight, if of any, injury to apples.

FURTHER OBSERVATIONS

A closer study of the efficiency of the spray mixtures under field conditions was made on a small scale in one of the variety orchards of the Station. Here, on April 5th, about the time the buds were beginning to unfold (principally in the case of Arkansas Black) a number of trees were given a thorough application of "Black Leaf 40" in water (1 to 1060) plus common laundry soap (4 lbs. to 100 gals.). Here again *malifoliae* was

Table I Showing Counts of Dead and Living Aphids (A. prunifoliae Fitch) *on Buds of Trees Sprayed with Nicotine Sulfate (40%) in water (1 to 1060) Plus Soap (4 lbs. to 100 gals.), April 5th. Counts made April 6 and 7.*

Buds			Aphids		
No.	Variety	Condition	Dead	Dying	Living (apparently sound)
1	Arkansas Black	Compact	97	0	2
2	" "	"	57	3	4
3	" "	"	36	1	1
4	" "	"	80	5	0
5	" "	Somewhat unfolded	63	0	1
6	" "	" "	37	5	14
7	" "	" " (slightly more than above)	40	2	3
8	York Imperial	Compact	30	0	0
9	" "	"	29	0	0
10	" "	"	20	5	0
11	" "	"	30	2	0
12	" "	"	39	0	0
13	Grimes Golden	"	24	4	0
14	" "	"	15	0	0
15	" "	"	24	0	0
16	Stayman Winesap	"	56	1	0
17	" "	Somewhat unfolded	38	0	0

scarce and the aphids involved were *prunifoliae*. On the two following days representative buds were plucked, and the dead and living aphids were counted.

The spraying, it should be added, was followed very shortly after by rain which continued for about three hours.

On April 19th, a number of trees in the same orchard, with flower clusters showing pink, which up to that time that spring had not in any way been treated, were given a thorough application of "Black Leaf 40" (1 to 1060) in lime sulfur (1 to 20). Clusters were collected the second day following the spraying and the dead and living aphids were counted.

Table II Showing Counts of Dead and Living Aphids (A. prunifoliae Fitch) *on Flower Cluster Buds of Trees Sprayed with Nicotine Sulfate (40%) (1 to 1060) in Lime Sulfur (1 to 20), April 19. Counts Made April 21.*

Clusters			Aphids			
			Dead		Living	
No.	Variety	Condition	Young	Old	Young	Old[1]
1	Roxbury Russet	Loose[2]	23	1	0	2
2	" "	Compact	2	0	48	8
3	" "	"	9	0	60	7
4	York Imperial	Loose	37	1	9	1
5	" "	Compact	7	0	21	3
6	Grimes Golden	Loose	75	2	5	1
7	" "	Compact	8	0	32	4
8	Arkansas Black	Loose	30	0	9	4
9	" "	Compact	6	0	64	13
10	" "	Loose	51	1	20	1
11	" "	Loose (partially)	14	8	0	0

The tables show at once that the nicotine-lime sulfur combination, at the time the flower clusters show pink, is far less effective than the nicotine-water and soap solution earlier in the season, as the spraying experiments in Cambria demonstrated. Secondly, (Table II) it was less effective in the case of the compact clusters. This is due, of course, to the fact that the aphids are able to work their way in among the stems and buds of the clusters where they escape the spray. It would be advisable, therefore (other conditions allowing), to delay this spray, if given, until the individual flower buds in the cluster have separated and the aphids are exposed. Thirdly, the same table evidences the well known partiality of *prunifoliae*

[1]These consisted of mature and advanced stage stem mothers; the "young" were first instar Second Generation individuals.

[2]Individual buds separated and standing apart.

(especially true of the stem mothers; 10, p. 29) for the flower clusters and flowers, which fact may make it a very important factor in fire-blight dissemination. In the fourth place, it should be noted (same table) that a very large proportion of the old aphids escaped destruction, which may argue a too high dilution of the nicotine. Finally, and certainly not to be overlooked, Table I suggests the importance of applying the early spray—against the newly hatched aphids—before the buds have unfolded too far—a fact emphasized by workers generally.

LITERATURE CITED

(1) Baker, A. C., and Turner, W. F., 1916. Rosy Apple Aphis. In Jour. Agr. Res., Vol. 7, No. 7, pp. 321-343, pl. 20-25.

(2) Brittain, W. H., 1916. Some Hemiptera Attacking the Apple. In Proc. Ent. Soc. Nova Scotia, 1915, No. 1, pp. 7-47.

(3) Brooks, C., and Fisher, D. F., 1916. Spot Diseases of the Apple. Better Fruit, Vol. 10, No. 8, February, pp. 13-15.

(4) Fitch, Asa, 1856. First Report on the Noxious, Beneficial and Other Insects of the State of New York, 176 p.

(5) Gillette, C. P., and Taylor, E. P., 1908. A Few Orchard Plant Lice. Col. Agr. Expt. Stan., Bul. 133, 48 p., 1 fig., 4 pl.

(6) Ross, W. A., 1915. Orchard Insects. In 45th Ann. Rept. Ent. Soc. Ont., 1914, pp. 22-24.

(7) Sanderson, E. D., 1901. Report of the Entomologist. In 12th Ann. Rept., Del. Agr. Expt. Stan., 1900, pp. 142-238, illus.

(8) ———— 1902. Report of the Entomologist. In 13th Ann. Rept., Del. Agr. Expt. Stan., 1901, pp. 127-199, illus.

(9) Smulyan, M. T., 1916. Observations on the Life Histories and Habits of the Species of Aphids Most Common on the Cultivated Apple in Virginia (Blacksburg) During the Season of 1915. In 10th Rept. of the State Entomologist and Plant Pathologist of Virginia, 1914-15, pp. 64-75.

(10) ———— 1918. Observations During 1916 of the Aphids Most Common on Apple. In 11th Rept. of the State Entomologist and Plant Pathologist of Virginia, 1916-17, pp. 27-39, 3 figs., 1 pl.

(11) ———— 1918. Key and Descriptions for the Separation and Determination of the First Instar Stem Mothers of the Three Species of Aphids Most Commonly Attacking the Cultivated Apple. In Psyche, Vol. 35, No. 2, April, pp. 19-23, 3 figs.

ANNUAL REPORT

OF THE

VIRGINIA POLYTECHNIC INSTITUTE

Agricultural Experiment Station

FOR THE PERIOD JULY 1, 1919, TO JUNE 30, 1927

CONTENTS

The more popular and immediately applicable results of the work of this Experiment Station are presented in Bulletins and Technical Bulletins, which are for general distribution. This report contains a brief statement of the work in progress and several articles which are not published elsewhere.

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

FOR THE PERIOD JULY 1, 1919, TO JUNE 30, 1927

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

CONTENTS

LETTER OF TRANSMITTAL

To His Excellency, Governor H. F. Byrd:

SIR: In accordance with the Federal laws, approved March 2, 1887, March 20, 1906, and February 24, 1925, I transmit for your consideration the report of the Virginia Agricultural Experiment Station for the period ending June 30, 1927. It includes a brief statement of the work completed or in progress, and the principal changes which have occurred since the issuance of the last report.

Respectfully submitted,

A. W. DRINKARD, JR., *Director*

January 31, 1928.

ORGANIZATION OF THE
VIRGINIA AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

THE EXECUTIVE COMMITTEE OF THE BOARD OF VISITORS OF THE VIRGINIA POLYTECHNIC INSTITUTE

ROBT. S. MOSS, Chairman	Burkes Garden, Tazewell County
T. GILBERT WOOD	Roanoke, Roanoke County
JAS. P. WOODS	Roanoke, Roanoke County
T. JUDSON WRIGHT	Norfolk, Norfolk County
J. A. BURRUSS, *ex officio*	Blacksburg, Montgomery County

STATION STAFF

J. A. BURRUSS, A.M., PH.D.	President
A. W. DRINKARD, JR., PH.D.	Director
H. L. PRICE, M.S.	Horticulturist
W. B. ELLETT, PH.D.	Chemist
W. J. SCHOENE, M.S.	Entomologist
T. B. HUTCHESON, M.S.	Agronomist
F. D. FROMME, PH.D.	Plant Pathologist and Bacteriologist
C. W. HOLDAWAY, M.S.	Dairy Husbandman
W. D. SAUNDERS	Milk Investigations
J. J. VERNON, M.S.	Agricultural Economist
ILENA M. BAILEY, B.S.	Home Economist
W. E. GARNETT, PH.D.	Rural Sociologist
H. H. HILL, M.S.	Associate Chemist
S. A. WINGARD, PH.D.	Associate Plant Pathologist
R. A. RUNNELLS, D.V.M.	Associate Animal Pathologist
W. S. HOUGH, PH.D.	Associate Entomologist
F. W. HOFMANN, PH.D.	Associate Horticulturist
N. A. PETTINGER, PH.D.	Associate Agronomist
G. W. UNDERHILL, M.SC.	Assistant Entomologist
F. J. SCHNEIDERHAN, M.S.	Assistant Plant Pathologist
R. C. MOORE, B.S.	Assistant Horticulturist
R. H. HURT, B.S.	Assistant Plant Pathologist
C. R. NOBLES, M.S.	Assistant Animal Husbandman
L. R. CAGLE, B.S.A.	Assistant Entomologist
J. F. EHEART, M.S.	Assistant Chemist
J. L. MAXTON, M.S.	Assistant Agricultural Economist
M. S. KIPPS, M.S.	Assistant Agronomist
C. H. HAMILTON,, M.S.	Assistant Rural Sociologist
L. E. STARR, D.V.M.	Assistant Animal Pathologist
D. C. HEITSHU, B.S.	Assistant Agricultural Engineer
V. R. HILLMAN, B.S.	Assistant Agricultural Engineer
A. M. WOODSIDE, M.S.	Assistant Entomologist
R. A. BALLINGER, M.A.	Assistant Agricultural Economist
E. F. DAVIS, B.S.	Assistant Plant Physiologist
C. I. WADE	Treasurer
R. R. SWOPE	Executive Clerk

COUNTY EXPERIMENT STATIONS

T. B. HUTCHESON, M.S.	Supervisor County Experiment Stations
W. W. GREEN (Bowling Green)	Superintendent Caroline Station
B. G. ANDERSON, B.S. (Appomattox)	Superintendent Appomattox Station
R. P. COCKE (Williamsburg)	Superintendent James City Station
P. T. GISH, B.S. (Fishersville)	Superintendent Augusta Station
T. L. COPLEY, B.S. (Chatham)	Superintendent Pittsylvania Station
O. P. STRAWN (Martinsville)	Superintendent Henry Station
H. C. MARSHALL (Charlotte C. H.)	Superintendent Charlotte Station
E. T. BATTEN, B.S. (Holland)	Superintendent Nansemond Station

Organization list corrected to March 1, 1928.
Bulletins and reports are mailed free to all residents of the State who apply for them.

Annual Report of the Virginia Agricultural Experiment Station

DIRECTOR'S REPORT

By A. W. Drinkard, Jr.

President Julian A. Burruss,
Virginia Polytechnic Institute.

Sir: I have the honor to submit the report of this station covering the period beginning July 1, 1919, and ending June 30, 1927.

The years immediately following the World War proved to be a rather trying period from the standpoint of administering the affairs of the station. The higher price levels of labor, feeding stuffs, fertilizers, printing and all other supplies required for carrying on the work of the station made it necessary to apply the strictest economy in expenditures and in many cases to curtail the amount of work undertaken. At that time the plan was adopted of concentrating the efforts of the station force on the most pressing problems in order to render the maximum service to the farmers of the State. In 1922 the General Assembly increased its appropriation to the station, as shown in the financial tables. In 1925, the Congress passed the Purnell Act, which authorized an appropriation of $20,000.00 per annum to each state for the further support of the agricultural experiment stations, at the same time providing that the appropriations under this act be increased by $10,000.00 per annum for the succeeding four years. Hence the financial strain was considerably relieved toward the latter part of this period, thus allowing the station to expand its services in several important lines of investigation.

Additions to Equipment, Structures, and Major Repairs

A cottage was built in 1920 for an employee of the agronomy department in order to have some one near the plats at all times. This cottage is 32 feet by 32 feet, with concrete foundation, half basement, five rooms, back and front porches, and metal roof. It cost about $2,500.00.

Lysimeter equipment was installed in 1921. It consists of a concrete cellar 43½ feet long, 7 feet wide, and 7 feet high, with soil tanks outside and suitable containers on the inside to catch the drainage from the soil tanks. This equipment cost about $2,500.00.

The small barn on the west side of the agronomy plats, originally built for experiments dealing with tuberculosis in cattle, was completely overhauled

Edition of 2,000 copies.

and remodeled to make it suitable for use in connection with field crops experiments at a cost of $350.00.

The agronomy barn, horse barn, and tool shed were painted in 1922 at a cost of $390.00. In 1923 a metal roof was put on the agronomy barn and a septic tank installed at a cost of $590.00.

The barn now used for cow feeding experiments in the dairy husbandry department was remodeled by the college in 1922 at a cost of $3,000.00. In addition to this the station installed in this barn, stanchions, feeding boxes, and other equipment needed for these experiments at a cost of $1,000.00. The station in 1922 and 1923 moved and re-erected two silos, placing them on concrete foundations; tile drains were installed to carry run-off water beyond the cow shed; a concrete runway was built and fenced by iron bars on both sides to connect the barn and shed; a manure pit was built and track for manure carrier was installed; a concrete floor was put in the cow shed; and several other minor betterments were made at the dairy barn, the entire cost being $4,300.00. A small boiler for use in the milk room was repaired at a cost of $50.00; a feed grinder purchased at a cost of $300.00; and a 10-horsepower motor and transformer purchased at a cost of $400.00.

In 1920 the station purchased 36 1/10 acres of land near Bowling Green at a cost of $2,707.50 as a permanent place for conducting the work at the Caroline County station. In the following year a six-room cottage was built on this place to keep the laborer near the work. This cottage cost $1,750.00. Also a barn costing $1,250.00 and a granary costing $400.00 were built.

In 1922 the station purchased 50 4/10 acres of land near Chatham at a cost of $6,300.00 to provide a permanent place for the work at the Pittsylvania County station. The following year several structures were built on this place: a grain and forage barn costing $1,475.00; and a tobacco barn with stripping-room attached, which cost $1,250.00.

The experimental farm near Staunton, owned by the State Board of Agriculture on which the work of the Augusta County station was conducted, was partly subject to overflow from a stream which passes through the farm, and for this reason the land was not satisfactory for field plat experiments. Hence the State Board of Agriculture in 1922 sold this farm and from the proceeds of the sale purchased a tract of 30 acres near Fishersville and erected on it a residence and barns. To the proceeds the State Board of Agriculture added a special appropriation of $750.00 to complete these buildings.

Every year during this period there were small betterments to existing structures, and additions to equipment, particularly to library and laboratory equipment. In this way the physical equipment of the station is gradually being improved.

During the period of time covered by this report the agricultural branch of the library has grown steadily. Books added by purchase or gift number

2,873; volumes added by binding were 2,412. The subscription and exchange list of journals and magazines increased from 168 to 254. A great many sets of journals, magazines, and pamphlets were completed by purchase of missing numbers. The catalogue has been completely refiled and over 30,000 catalogue cards and a 30-drawer catalogue cabinet were added. About 40,000 pamphlets and 2,000 volumes of magazines were acquired; many of these have been bound and others filed in cabinet cases and closed cabinets. Shelving sufficient for 4,000 volumes was installed and other minor items of equipment were placed in the branch library.

Changes in the Staff

Appointments

D. J. BERGER, superintendent Pittsylvania County station, October 1, 1919.

M. E. GARDNER, assistant horticulturist, October 1, 1919.

J. C. HART, acting associate agronomist, October 1, 1919.

R. C. THOMAS, assistant plant pathologist, November 1, 1919.

E. R. HODGSON, superintendent Augusta County station, January 1, 1920.

J. F. EHEART, assistant plant pathologist, March 1, 1920.

H. C. MARSHALL, superintendent Charlotte County station, March 1, 1921.

FRANCES M. BENSON, librarian, September 1, 1921.

F. J. SCHNEIDERHAN, assistant plant pathologist, March 14, 1922.

T. L. COPLEY, superintendent Pittsylvania County station, June 15, 1922.

W. D. SAUNDERS, dairy products investigations, July 1, 1922.

C. E. SEITZ, agricultural engineer, July 1, 1922.

E. C. MILLER, business manager, July 1, 1922.

R. C. MOORE, assistant horticulturist, July 31, 1922.

D. A. TUCKER, assistant horticulturist, September 25, 1922.

W. S. HOUGH, assistant entomologist, December 1, 1922.

BETTYE E. BELL, librarian, March 1, 1923.

R. H. HURT, assistant plant pathologist, June 5, 1923.

J. J. VERNON, associate agricultural economist, June 15, 1923.

M. S. KIPPS, assistant in agronomy, September 15, 1923.

O. P. STRAWN, superintendent Henry County station, October 1, 1923.

C. R. NOBLES, assistant animal husbandman, October 15, 1923.

P. C. MANLEY, superintendent Augusta County station, January 1, 1924.

ANNA P. CUNNINGHAM, librarian, July 1, 1924.

R. A. RUNNELLS, associate animal pathologist, August 1, 1924.

J. F. EHEART, assistant chemist, February 1, 1925.

C. N. PRIODE, assistant in plant pathology, June 6, 1925.

ELLEN A. REYNOLDS, home economist, July 1, 1925.

E. L. LANGSFORD, assistant agricultural economist, July 1, 1925.

W. E. GARNETT, rural sociologist, August 1, 1925.

W. G. NUNN, assistant agricultural engineer, August 1, 1925.

BLANCHE HURD, executive clerk, February 1, 1926.

P. T. GISH, superintendent Augusta County station, February 1, 1926.

C. L. PICKARD, assistant rural sociologist, July 1, 1926.

W. J. SCHOENE, entomologist, July 1, 1926.

G. W. UNDERHILL, assistant entomologist, July 1, 1926.

L. R. CAGLE, assistant entomologist, July 1, 1926.

F. W. HOFMANN, associate horticulturist, July 15, 1926.

M. P. MILLER, assistant chemist, September 13, 1926.

D. C. HEITSHU, assistant agricultural engineer, January 1, 1927.

V. R. HILLMAN, assistant agricultural engineer, January 1, 1927.

J. L. MAXTON, assistant agricultural economist, February 14, 1927.

A. M. WOODSIDE, assistant entomologist, March 15, 1927.

C. H. HAMILTON, assistant rural sociologist, June 15, 1927.

Resignations, Separations, and Transfers

C. F. WARREN, assistant horticulturist, September 16, 1919.

J. C. HART, superintendent Pittsylvania County station, October 1, 1919.

R. H. COOK, superintendent Augusta County station, November 1, 1919.

J. C. HART, acting associate agronomist, was transferred to the Extension Division, June 30, 1920.

R. C. THOMAS, assistant plant pathologist, was transferred to the Extension Division, November 1, 1920.

J. F. EHEART, assistant plant pathologist, March 1, 1921.

ANNA E. MURRILL, librarian, August 31, 1921.

M. O. WILSON, superintendent Charlotte County station, March 1, 1922.

A. N. HODGSON, superintendent Henry County station, April 15, 1922.

D. J. BERGER, superintendent Pittsylvania County station, June 15, 1922.

M. E. GARDNER, assistant horticulturist, September 15, 1922.

FRANCES M. BENSON, librarian, was transferred to the main library, March 1, 1923.

F. S. GLASSETT, assistant agronomist, September 1, 1923.

R. E. HUNT, animal husbandman, was transferred entirely to college duties, October 15, 1923.

E. R. HODGSON, superintendent Augusta County station, December 1, 1923.

BETTYE E. BELL, librarian, July 1, 1924.

A. B. MASSEY, associate bacteriologist, was transferred entirely to college duties, July 1, 1924.

D. A. TUCKER, assistant horticulturist, was transferred to college and extension duties, September 1, 1924.

G. S. RALSTON, field horticulturist, September 1, 1924.

W. G. HARRIS, associate chemist, February 1, 1925.

C. E. SEITZ, agricultural engineer, March 1, 1925.

J. HOP. TAFT, assistant treasurer, died October 22 1925.

J. B. FOGLEMAN, executive clerk, was transferred to the treasurer's office and became assistant treasurer, January 1, 1926.

P. C. MANLEY, superintendent Augusta County station, February 1, 1926.

W. G. NUNN, assistant agricultural engineer, was transferred to the Extension Division, January 1, 1927.

C. N. PRIODE, assistant in plant pathology, January 1, 1927.

BLANCHE HURD OLINGER, executive clerk, May 31, 1927.

E. L. LANGSFORD, assistant agricultural economist, June 30, 1927.

C. L. PICKARD, assistant rural sociologist, was transferred to the Extension Division, June 30, 1927.

Promotions and Leaves of Absence

S. A. WINGARD, from assistant to associate plant pathologist, June 5, 1923.

T. K. WOLFE, from associate agronomist to agronomist, June 5, 1923.

J. J. VERNON, from associate to agricultural economist, June 10, 1924.

W. S. HOUGH, from assistant to associate entomologist, June 10, 1924.

M. S. KIPPS, from assistant in agronomy to assistant agronomist, March 1, 1926.

T. K. WOLFE, associate agronomist, was granted leave of absence to pursue graduate work at Cornell University during the sessions of 1919-1920 and 1920-1921.

M. O. WILSON, superintendent of the Charlotte County station was granted a year's leave of absence beginning March 1, 1921, to assist in organizing the tobacco growers' cooperative association; however, Mr. Wilson resigned the position with this station at the end of the leave.

S. A. WINGARD, assistant plant pathologist, was granted leave of absence to pursue graduate work at Columbia University for the sessions of 1922-1923 and 1924-1925.

W. S. HOUGH, assistant entomologist, was granted leave of absence to pursue graduate work at the University of Ohio for two months in the spring of 1924, and for six months during the session of 1924-1925.

J. F. EHEART, assistant chemist, was granted leave of absence to pursue graduate work at Columbia University during the session of 1926-1927.

FINANCES

Tables 1 to 8, inclusive, set forth the fiscal transactions of the station for the period covered by the report. The station received each year from the Federal Government $15,000.00 under the Hatch Act and a like amount under the Adams Act. For the year ending June 30, 1926, the station received $20,000 from the Federal Government under the Purnell Act; and for the year ending June 30, 1927, the station received $30,000.00 under the Purnell Act. The supplemental fund includes revenues derived from the sale of farm crops, orchard fruits, live stock, and milk which are produced incidentally in our experiments and investigations supported by federal funds.

The state fund includes the appropriations made by the General Assembly of Virginia for support of the work of the station; and the revenues derived from the sale of produce, and so forth, incidental to the experiments cared for by this fund. The state appropriation year does not coincide with the federal fiscal year, and therefore the financial tables do not correspond exactly with the annual appropriations from the General Assembly, which were as follows:

For the year ending:	Appropriation
February 28, 1921	$30,000.00
February 28, 1922	30,000.00
February 28, 1923	50,925.00

For the year ending:	Appropriation
February 29, 1924	52,925.00
February 28, 1925	62,900.00
February 28, 1926	62,900.00
February 28, 1927	63,000.00
February 29, 1928	63,000.00

The General Assembly in 1926 abolished the State Board of Crop Pest Commissioners and transferred the investigational and research work of this board to this station, and its control and regulatory work to the Department of Agriculture and Immigration, effective July 1, 1926. In this transfer, W. J. Schoene, entomologist; G. W. Underhill, assistant entomologist; and L. R. Cagle, assistant entomologist, were made members of the station staff. W. S. Hough, associate entomologist, was already a member of the station staff for part time and at this transfer he became a full-time member. The station was allocated $8,557.78 out of the original appropriation to the State Board of Crop Pest Commissioners for the year ending February 28, 1927; and $12,135.00 for the year ending February 29, 1928.

The State Board of Agriculture continued its allotment of funds for the support of the Augusta, Charlotte, and Henry County Stations. These allotments were as follows:

For the year ending:	Allotment
February 28, 1921	$8,400.00
February 28, 1922	8,300.00
February 28, 1923	8,375.00
February 29, 1924	8,325.00
February 28, 1925	9,675.00
February 28, 1926	9,655.00
February 28, 1927	10,000.00
February 29, 1928	10,000.00

TABLE 1.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1919-1920.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$ .00	$30,000.00	$9,450.00
Balances from previous year	.00	.00	5,524.11	7,230.42	402.00
Farm products, etc.	.00	.00	9,722.47	11,448.14	1,673.79
Totals	$15,000.00	$15,000.00	$15,246.58	$48,678.56	$11,525.79
DISBURSEMENTS:					
Salaries	$9,629.79	$10,437.50	$643.87	$15,709.30	$4,799.91
Labor	3,179.89	2,574.34	2,038.96	6,149.30	2,081.75
Publications	2.50	.00	.00	2,752.43	.00
Postage and stationery	262.51	.00	297.59	158.43	92.31
Freight and express	101.12	71.89	127.63	399.87	164.74
Heat, light, water, and power	539.69	1.32	2.71	73.26	28.47
Chemicals and laboratory supplies	2.60	295.53	45.95	2.05	.00
Seeds, plants, and sundry supplies	376.21	231.26	520.52	2,394.98	585.35
Fertilizers	336.63	40.10	625.21	1,497.94	593.85
Feeding stuffs	.00	960.99	2,921.55	3,996.03	231.31
Library	15.76	.00	72.90	84.40	.00
Tools, machinery, and appliances	257.98	41.15	743.59	388.52	435.33
Furniture and fixtures	7.48	2.20	10.80	.00	.00
Scientific apparatus and specimens	.00	6.65	81.65	.00	.00
Live stock	.00	.00	44.00	3,244.15	220.50
Traveling expenses	246.40	212.07	749.99	2,216.38	300.33
Contingent expenses	20.00	.00	27.00	197.42	128.02
Buildings and land	21.44	125.00	2,457.04	7,255.00	1,581.86
Balances	.00	.00	3,835.62	2,159.10	282.06
Totals	$15,000.00	$15,000.00	$15,246.58	$48,678.56	$11,525.79

TABLE 2.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1920-1921.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$ .00	$30,000.00	$8,350.00
Balances from previous year	.00	.00	3,835.62	2,159.10	282.06
Farm products, etc.	.00	.00	7,599.30	3,291.88	2,444.34
Totals	$15,000.00	$15,000.00	$11,434.92	$35,450.98	$11,076.40
DISBURSEMENTS:					
Salaries	$9,618.26	$9,546.66	$800.00	$14,664.60	$5,500.00
Labor	2,849.12	3,064.48	644.22	4,157.12	2,023.20
Publications	316.09	.00	1,174.37	.00	.00
Postage and stationery	222.10	12,43	229.23	174.24	89.09
Freight and express	87.52	63.38	152.79	181.60	32.65
Heat, light, water, and power	528.97	1.25	92.30	68.79	13.50
Chemicals and laboratory supplies	76.72	37.08	14.60	11.70	.00
Seeds, plants, and sundry supplies	332.64	96.04	283.25	786.88	640.62
Fertilizers	153.55	206.75	21.20	1,188.61	251.36
Feeding stuffs	36.00	1,405.26	1,129.08	2,658.37	525.25
Library	379.88	2.75	9.59	10.00	.00
Tools, machinery, and appliances	230.43	3.25	475.24	351.89	91.65
Furniture and fixtures	3.16	.00	46.13	2.50	.00
Scientific apparatus and specimens	10.59	367.92	.00	8.72	.00
Live stock	2.00	.00	83.00	2,125.72	165.00
Traveling expenses	85.24	45.16	757.17	1,486.07	40.69
Contingent expenses	.00	.00	45.00	96.85	2.50
Buildings and land	67.73	147.59	776.35	891.02	700.20
Balances	.00	.00	4,701.40	6,586.30	1,000.69
Totals	$15,000.00	$15,000.00	$11,434.92	$35,450.98	$11,076.40

TABLE 3.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1921-1922.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$ .00	$36,975.00	$8,322.50
Balances from previous year	.00	.00	4,701.40	6,586.30	1,000.69
Farm products, etc.	.00	.00	4,097.33	4,007.93	722.24
Totals	$15,000.00	$15,000.00	$8,798.73	$47,569.23	$10,045.43
DISBURSEMENTS:					
Salaries	$9,714.92	$10,224.80	$ .00	$16,119.84	$4,924.92
Labor	3,013.10	3,154.29	528.94	4,200.54	2,078.26
Publications	263.64	.00	217.57	2,618.96	.00
Postage and stationery	325.80	.00	89.15	274.03	74.89
Freight and express	145.28	109.05	229.45	267.04	20.55
Heat, light, water, and power	57.82	.00	505.20	16.90	10.50
Chemicals and laboratory supplies	21.22	64.67	3.84	330.42	.00
Seeds, plants, and sundry supplies	721.26	217.73	217.19	803.10	334.90
Fertilizers	115.28	120.65	275.03	723.20	313.15
Feeding stuffs	71.04	746.82	1,100.11	2,574.33	24.40
Library	186.50	.00	76.15	294.38	.00
Tools, machinery, and appliances	177.59	76.71	137.89	392.46	167.10
Furniture and fixtures	94.97	1.20	12.15	113.69	.00
Scientific apparatus and specimens	.00	54.45	.00	128.52	.00
Live stock	.00	.00	118.70	1,990.95	4.50
Traveling expenses	40.00	92.08	138.75	1,935.87	146.88
Contingent expenses	.00	.00	20.00	59.23	229.15
Buildings and land	51.58	137.55	1,031.41	5,594.05	444.20
Balances	.00	.00	4,097.20	9,131.72	1,272.03
Totals	$15,000.00	$15,000.00	$8,798.73	$47,569.23	$10,045.43

TABLE 4.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1922-1923.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$ .00	$51,591.64	$ 6,268.75
Balances from previous year	.00	.00	4,144.95	9,131.72	1,272.03
Farm products, etc.	.00	.00	5,429.56	5,392.32	738.52
Totals	$15.000,00	$15,000.00	$ 9,574.51	$66,115.68	$ 8,279.30*
DISBURSEMENTS:					
Salaries	$10,195.97	$9,449.88	$ .00	$25,345.70	$3,499.92
Labor	3,099.69	3,157.03	955.69	4,037.89	2,171.67
Publications	.00	.00	7.70	1,574.78	.00
Postage and stationery	156.63	1.25	162.16	380.68	35.45
Freight and express	112.42	100.19	115.26	399.17	20.72
Heat, light, water, and power	23.01	20.06	591.98	6.58	25.48
Chemicals and laboratory supplies	36.21	176.83	27.54	91.00	.00
Seeds, plants, and sundry supplies	511.28	375.73	261.39	1,083.64	627.03
Fertilizers	320.69	310.00	45.00	1,035.85	336.31
Feeding stuffs	2.98	495.63	1,130.79	2,660.73	106.96
Library	160.55	.00	526.41	13.75	.00
Tools, machinery, and appliances	192.72	101.68	1,184.87	658.92	101.95
Furniture and fixtures	45.84	.00	11.72	88.45	65.65
Scientific apparatus and specimens	35.06	533.80	1.48	167.09	.00
Live stock	.00	.00	384.00	2,952.26	.00
Traveling expenses	9.20	92.76	173.40	3,203.53	297.58
Contingent expenses	.00	.00	30.00	54.80	139.00
Buildings and land	97.75	185.16	1,115.18	13,185.07	1,514.63
Balances	.00	.00	2,849.94	9,175.79	.00
Totals	$15,000.00	$15,000.00	$9,574.51	$66,115.68	$8,942.35*

*The disbursements in this fund exceed the receipts by $663.05. Due to a clerical error the total appropriation for this period had not been received when the books were closed. The correction will appear in the next report.

TABLE 5.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1923-1924.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$ .00	$56,250.00	$8,662.50
Balance from previous year	.00	.00	2,849.94	9,175.79	Deficit 663.05*
Farm products, etc.	.00	.00	5,791.69	2,692.11	879.81
Totals	$15,000.00	$15,000.00	$8,641.63	$68,117.90	$8,879.26
DISBURSEMENTS:					
Salaries	$10,607.07	$10,685.00	$ .00	$33,714.82	$3,733.30
Labor	3,246.52	3,447.38	1,755.87	6,700.66	1,740.58
Stationery and office supplies	90.26	10.40	3.00	613.63	19.00
Scientific supplies, consumable	15.53	220.15	16.47	3.81	.00
Feeding stuffs	1.35	110.50	1,861.78	807.72	46.98
Sundry supplies	391.79	102.56	468.20	3,038.29	772.31
Fertilizers	67.51	.00	139.78	1,707.39	479.19
Communication service	101.35	.00	33.60	154.81	34.05
Travel expenses	24.65	125.50	50.66	5,018.97	304.72
Transportation of things	54.22	4.95	25.52	657.45	11.29
Publications	12.58	.00	679.45	2,041.77	.00
Heat, light, water, and power	46.38	49.20	509.57	68.06	27.22
Furniture, furnishings, and fixtures	38.45	5.25	24.42	890.51	.00
Library	106.99	.00	5.00	1,517.51	.00
Scientific equipment	.00	64.05	6.81	592.27	.00
Live stock	.00	.00	130.00	500.00	.00
Tools, machinery, and appliances	62.57	38.35	70.38	2,255.63	150.99
Buildings and land	112.78	136.71	386.96	2,749.31	425.37
Contingent expenses	20.00	.00	40.80	390.66	39.69
Balances	.00	.00	2,433.36	4,694.63	1,094.57
Totals	$15,000.00	$15,000.00	$8,641.63	$68,117.90	$8,879.26

*Subtract this item. See note under Table 4.

TABLE 6. — FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1924-1925.

	Hatch Fund	Adams Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$ .00	$62,900.00	$7,256.25
Balances from previous year	.00	.00	2,433.36	4,694.63	1,094.57
Farm products, etc.	.00	.00	6,948.35	2,424.95	315.20
Totals	$15,000.00	$15,000.00	$9,381.71	$70,019.58	$8,666.02
DISBURSEMENTS:					
Salaries	$10,169.92	$11,236.99	$100.00	$32,158.83	$4,674.93
Labor	1,948.47	2,764.73	602.93	10,998.09	1,682.73
Stationery and office supplies	114.20	2.80	.00	179.81	.00
Scientific supplies, consumable	101.90	92.02	.00	389.91	.00
Feeding stuffs	103.94	303.05	2,158.48	1,345.02	49.67
Sundry supplies	553.51	71.62	141.80	1,654.12	559.75
Fertilizers	323.47	.00	.00	1,329.17	403.74
Communication service	204.48	.00	.00	253.59	44.95
Travel expenses	162.83	.00	36.57	5,569.89	158.98
Transportation of things	126.43	86.66	93.15	319.78	26.63
Publications	402.50	.00	468.54	3,324.01	.00
Heat, light, water, and power	70.22	.00	500.00	70.14	26.60
Furniture, furnishings, and fixtures	87.30	21.15	20.90	967.51	.00
Library	155.10	.00	726.45	572.39	.00
Scientific equipment	101.07	407.88	.00	699.88	5.00
Live stock	110.00	.00	120.00	182.80	.00
Tools, machinery, and appliances	104.99	8.60	1.25	687.71	180.91
Buildings and land	139.67	4.50	22.35	2,645.32	823.34
Contingent expenses	20.00	.00	13.34	86.27	7.00
Balances	.00	.00	4,375.95	6,585.34	21.79
Totals	$15,000.00	$15,000.00	$9,381.71	$70,019.58	$8,666.02

TABLE 7.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1925-1926.

	Hatch Fund	Adams Fund	Purnell Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:						
Appropriations	$15,000.00	$15,000.00	$20,000.00	$ .00	$62,933.36	$9,655.00
Balance from previous year	.00	.00	.00	4,375.95	6,585.34	21.79
Farm products, etc.	.00	.00	.00	3,859.81	5,820.76	838.24
Totals	$15,000.00	$15,000.00	$20,000.00	$8,235.76	$75,339.46	$10,515.03
DISBURSEMENTS:						
Salaries	$8,830.01	$14,805.00	$11,280.97	$22.50	$31,992.24	$4,850.00
Labor	2,796.25	143.38	1,789.71	1,789.63	9,022.88	1,588.23
Stationery and office supplies	109.82	.00	492.64	1.63	165.90	9.00
Scientific supplies, consumable	370.21	29.97	.00	62.02	125.75	.00
Feeding stuffs	1.35	.00	.00	2,370.15	3,518.02	82.14
Sundry supplies	484.05	1.56	.00	184.26	1,625.13	596.51
Fertilizers	84.00	.00	.00	236.00	1,789.08	411.87
Communication service	151.15	.50	153.37	12.86	322.92	29.47
Travel expenses	266.34	.00	2,962.35	134.44	3,050.17	90.41
Transportation of things	217.76	.00	48.55	176.14	360.10	19.90
Publications	128.61	.00	668.20	13.14	3,653.79	.00
Heat, light, water, and power	106.97	.00	.00	15.92	646.97	18.31
Furniture, furnishings, and fixtures	45.06	1.50	1,811.81	25.32	455.18	3.50
Library	204.85	.00	5.00	203.62	297.74	.00
Scientific equipment	291.55	.59	325.00	13.22	350.49	.00
Live stock	.00	.00	.00	113.70	2,534.92	.00
Tools, machinery, and appliances	139.80	.00	449.25	41.44	622.45	589.45
Buildings and land	749.07	17.50	13.15	86.72	4,338.73	941.43
Contingent expenses	23.15	.00	.00	6.00	87.17	1,164.96
Balances	.00	.00	.00	2,727.05	10,379.83	119.85
Totals	$15,000.00	$15,000.00	$20,000.00	$8,235.76	$75,339.46	$10,515.03

TABLE 8.—FINANCIAL REPORT. THE VIRGINIA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH FEDERAL AND STATE APPROPRIATIONS, 1926-1927.

	Hatch Fund	Adams Fund	Purnell Fund	Supplemental Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:						
Appropriations	$15,000.00	$15,000.00	$30,000.00	$ .00	$75,602.78	$10,000.00
Balance from previous year	.00	.00	.00	2,727.05	10,379.83	119.85
Farm products, etc.	.00	.00	.00	4,243.11	10,424.83	460.89
Totals	$15,000.00	$15,000.00	$30,000.00	$6,970.16	$96,407.44	$10,580.74
DISBURSEMENTS:						
Salaries	$9,025.00	$14,656.65	$16,118.91	$189.60	$49,539.36	$5,389.98
Labor	3,078.42	103.97	2,349.90	1,597.92	10,180.90	2,355.48
Stationery and office supplies	118.99	.00	289.97	34.50	357.70	14.20
Scientific supplies, consumable	235.35	.00	.00	.70	479.43	.00
Feeding stuffs	.00	228.58	.00	2,010.94	3,830.33	116.10
Sundry supplies	536.31	.00	.30	24.40	2,768.58	749.29
Fertilizers	305.08	.00	.00	.00	1,528.10	382.44
Communication service	315.33	.00	137.23	9.42	276.07	63.81
Travel expenses	311.31	.00	4,824.78	.00	4,234.03	98.14
Transportation of things	124.30	.00	32.95	112.84	609.46	13.84
Publications	53.00	.00	4,648.23	.00	3,227.63	.00
Heat, light, water, and power	99.39	.00	1.60	13.26	602.88	39.30
Furniture, furnishings, and fixtures	112.57	.00	429.61	12.85	305.33	.00
Library	295.69	.00	84.60	.00	1,461.23	.00
Scientific equipment	124.39	.00	15.94	.00	36.83	.00
Live stock	.00	.00	.00	7.00	3,397.79	1.80
Tools, machinery, and appliances	205.36	9.05	640.84	27.60	1,729.89	229.11
Buildings and land	59.51	1.75	425.14	95.63	2,732.73	541.41
Contingent expenses	.00	.00	.00	180.00	607.62	25.36
Balances	.00	.00	.00	2,653.50	8,501.55	560.48
Totals	$15,000.00	$15,000.00	$30,000.00	$6,970.16	$96,407.44	$10,580.74

PUBLICATIONS

Publications reporting the results of station work were issued on a number of subjects during this period. The list which follows gives the principal publications.

BULLETINS

No. 222.—The nematode disease of wheat in Virginia; by F. D. Fromme; 12 pages, 4 figures; August, 1919.
No. 223.—Dusting experiments in peach and apple orchards; by F. D. Fromme and G. S. Ralston; 16 pages, 2 figures; November, 1919.
No. 224.—Dusting experiments in peach and apple orchards in 1920; by F. D. Fromme, G. S. Ralston, and J. F. Eheart; 12 pages, 1 figure; March, 1921.
No. 225.—Wintering dairy heifers; by R. E. Hunt; 15 pages, 2 figures, 3 graphs; June, 1921.
No. 226.—The yellows disease of cabbage in Southwest Virginia; by F. D. Fromme; 9 pages, 4 figures; November, 1921.
No. 227.—Silage experiments; by T. B. Hutcheson and T. K. Wolfe; 16 pages; March, 1922.
No. 228.—Blackfire and wildfire of tobacco and their control; by F. D. Fromme and S. A. Wingard; 19 pages, 9 figures; April, 1922.
No. 229.—Experiments with cotton and peanuts; by E. T. Batten; 22 pages, 5 figures; October, 1922.
No. 230.—Experiments in spraying and dusting tomatoes; by F. D. Fromme; 15 pages, 4 figures; November, 1922.
No. 231.—Experiments with dark tobacco and other crops; by B. G. Anderson; 19 pages, 4 figures; February, 1923.
No. 232.—The squash lady-bird beetle; by G. W. Underhill; 24 pages, 7 figures; July, 1923.
No. 233.—Experiments with bright tobacco and other crops grown on bright tobacco farms; by T. B. Hutcheson and D. J. Berger; 19 pages; September, 1923.
No. 234.—The present status of the oriental fruit moth in northern Virginia; by Louis A. Stearns; 28 pages, 9 figures; February, 1924.
No. 235.—Soybean culture; by T. K. Wolfe; 32 pages, 14 figures; March, 1924.
No. 236.—Apple scab and its control in Virginia; by F. J. Schneiderhan and F. D. Fromme; 29 pages, 6 figures; March, 1924.
No. 237.—Lime and its relation to crop production in Virginia; by T. B. Hutcheson and T. K. Wolfe; 20 pages, 4 figures; November, 1924.
No. 238.—Sheep management in Southwest Virginia as shown by a survey of 100 farms; by C. R. Nobles; 20 pages; December, 1924.
No. 239.—The dry-mix spray for peaches; by F. J. Schneiderhan and R. H. Hurt; 16 pages, 2 figures; January, 1925.
No. 240.—The agricultural situation in Roanoke and its trade territory; by J. J. Vernon and H. I. Richards; 70 pages, 28 figures; March, 1925.
No. 241.—Causes of profit or loss on Virginia tobacco farms; by J. J. Vernon and M. J. B. Ezekiel; 71 pages, 2 charts; November, 1925.
No. 242.—Experiments with sun-cured tobacco and other crops grown in rotation with it; by W. W. Green; 15 pages; November, 1925.
No. 243.—Dried apple pomace compared with dried beet pulp and with corn silage in feeding dairy cows for milk production; by C. W. Holdaway; 11 pages; November, 1925.
No. 244.—Honeysuckle eradication in Virginia apple orchards; by R. H. Hurt; 8 pages; January, 1926.
No. 245.—Apple disease studies in northern Virginia; by F. J. Schneiderhan; 35 pages, 4 figures; February, 1926.
No. 246.—Pastures for hogs reduce the cost of producing pork in eastern Virginia; by C. R. Nobles; 16 pages, 2 figures; February, 1926.

No. 247.—Experiments with alfalfa in eastern Virginia; by R. P. Cocke; 16 pages, 3 figures; March, 1926.

No. 248.—Codling moth investigations in Virginia; by W. S. Hough, L. A. Stearns, C. R. Willey, and L. R. Cagle; 27 pages, 8 figures; April, 1926.

No. 249.—Renting farms in Virginia; by Clifford C. Taylor and J. J. Vernon; 32 pages, 10 figures; May, 1926.

No. 250.—The relation between dietary habits and health of children in rural sections of Virginia; by Ellen A. Reynolds; 39 pages, 3 figures; August, 1926.

No. 251.—Studies on the potato tuber moth during the winter 1925-1926; by G. W. Underhill; 21 pages, 3 figures; August, 1926.

No. 252.—Red clover experiments; by T. K. Wolfe and M. S. Kipps; 24 pages, 12 figures; December, 1926.

No. 253.—The effects of rotations, fertilizers, lime and organic matter on the production of corn, wheat, and hay; by T. K. Wolfe and M. S. Kipps; 50 pages, 31 figures; February, 1927.

No. 254.—New methods of bitter rot control; by R. H. Hurt and F. J. Schneiderhan; 22 pages, 6 figures; February, 1927.

No. 255.—Cost of producing Virginia dark and bright tobacco; by A. P. Brodell; 45 pages, 17 figures; March, 1927.

No. 256.—Rural organizations in relation to rural life in Virginia, with special reference to organizational attitudes; by W. E. Garnett; 110 pages, 20 figures; May, 1927.

No. 257.—Factors affecting returns from the dairy enterprise in the Shenandoah Valley; by J. J. Vernon, C. W. Holdaway, Mordecai Ezekiel, and R. S. Kifer; 87 pages, 16 figures; June, 1927.

No. 258.—Systems of beef cattle farming for southwestern Virginia; by E. L. Langsford and J. B. Hutson; 47 pages, 10 figures; June, 1927.

Technical Bulletins

No. 20.—The effects of high protein and high energy rations in feeding dairy cows; by W. B. Ellett and C. W. Holdaway; 16 pages; June, 1920.

No. 21.—The life history of the oriental fruit moth in northern Virginia; by Louis A. Stearns; 46 pages, 1 plate; March, 1921.

No. 22.—The larger corn stalk-borer in Virginia; by W. J. Phillips, G. W. Underhill, and F. W. Poos; 30 pages, 4 figures, and 4 plates; June, 1921.

No. 23.—Feeding standards for milk production; by W. B. Ellett, C. W. Holdaway, and W. G. Harris; 52 pages; December, 1921.

No. 24.—A study of the influence of the lime-magnesia ratio on soils under continuous cultivation; by H. H. Hill; 15 pages, 1 chart; March, 1922.

No. 25.—Blackfire and wildfire of tobacco; by F. D. Fromme and S. A. Wingard; 43 pages, 18 figures, and 2 color plates; April, 1922.

No. 26.—A biometrical analysis of characters of maize and of their inheritance; by T. K. Wolfe; 70 pages, 26 figures; February, 1924.

No. 27.—The effects of fertilizers and hybridization on maturity and yield of corn; by T. B. Hutcheson and T. K. Wolfe.

No. 28.—The comparative value of peanut meal, cottonseed meal, and soybean meal as sources of protein for milk production; by C. W. Holdaway, W. B. Ellett, and W. G. Harris; 54 pages, 2 plates; February, 1925.

No. 29.—Biology and control of Comstock's mealy bug on the umbrella catalpa; by W. S. Hough; 27 pages, 7 figures, and 5 diagrams; February, 1925.

No. 30.—A study of germination, maturity, and yield in corn; by T. K. Wolfe; 35 pages, 1 figure; January, 1927.

Contributions to Journals and Other Publications

Black, O. F., Eggleston, W. W., Kelly, J. W., and Turner, H. C. Poisonous properties of *Bikukulla cucullaria* (Dutchman's breeches) and *B. Canadensis* (squirrel corn). Journal of Agricultural Research 23:69-78; 1 plate; 1923.

Daniels, A. M., Seitz, C. E., and Glenn, J. C. Power for the farm from small streams. U. S. Department of Agriculture Farmers' Bulletin No. 1430; 35 pages, 40 figures; 1925.

Ellett, W. B., and Harris, W. G. Cooperative experiments for the composting of phosphate rock and sulphur. Soil Science 10:315-325; 1920.

Ellett, W. B., and Wolfe, T. K. The relation of fertilizers to Hessian fly injury and winter-killing of wheat. Journal of the American Society of Agronomy 13:12-14; 1921.

Ellett, W. B., and Wolfe, T. K. The effect of fertilizers on yield and market condition of corn. Journal of the American society of Agronomy 14:153-158; 1922.

Fromme, F. D. Incidence of loose-smut in wheat varieties. Phytopathology 11: 507-510; 1921.

Fromme, F. D., and Wingard, S. A. Varietal susceptibility of beans to rust. Journal of Agricultural Research 21:385-404; 5 plates; 1921.

Fromme, F. D. The rust of cowpeas. Phytopathology 14:67-79; 1 figure and 1 plate; 1924.

Fromme, F. D. The apple root-stock problem. Proceedings of the Virginia State Horticultural Society (1925) :152-155; 1926.

Fromme, F. D. Susceptibility of wheat varieties and selections to loose smut. Phytopathology 16:86-87; 1926.

Fromme, F. D., Wingard, S. A., and Priode, C. N. Ringspot of tobacco; an infectious disease of unknown cause. Phytopathology 17:321-328; 6 figures; 1927.

Hill, H. H. Decomposition of organic matter in soil. Journal of Agricultural Research 33:77-99; 2 figures; 1926.

Holdaway, C. W., Ellett, W. B., and Harris, W. G. Protein requirements for the growth of cattle. Bulletin of the National Research Council Vol. 2:257-288; 1921.

Hough, W. S. Observations on two mealy bugs, *Trionymus trifolii* Forbes and *Pseudococcus maritimus* Ehrh. Entomological News 33:171-176; 1922.

Hough, W. S. Controlling *Pseudococcus comstocki* Kuw. on catalpa. Journal of Economic Entomology 18:823-827; 1925.

Hough, W. S. The anal lobe of *Pseudococcus comstocki* Kuw. Entomological News 36:52-54; 1 figure; 1925.

Hough, W. S. The internal anatomy of the clover root mealy bug (*Trionymus trifolii* Forbes). (*Homoptera Coccidae*). Bulletin of Entomological Research 16:25-29; 6 figures; 1925.

Hough, W. S. The red-banded leaf-roller. Proceedings of the Virginia State Horticultural Society (1925):129-132; 1926.

Hunt, R. E. Selecting Holstein-Friesian sires for high yearly production. The Journal of Heredity 12:369-384; 8 illustrations; 1921.

Hurt, R. H. Control of bitter rot. Proceedings of the Virginia State Horticultural Society (1925):134-140; 1925.

Hurt, R. H. The importance of removal of mummies and affected fruit in apple bitter rot control. Phytopathology 15:56; 1925.

Hutcheson, T. B., and Wolfe, T. K. The correlation between time of germination, maturity, and yield of corn. Journal of the American Society of Agronomy 16:483-485; 1924.

Massey, A. B. A study of *Bacillus aroideae* Townsend, the cause of a soft rot of tomato, and *B. carotovorus* Jones. Phytopathology 14:460-477; 3 figures; 1924.

Massey, A. B. Antagonism of the walnuts (*Juglans nigra* L. and *J. Cinerea* L.) in certain plant associations. Phytopathology 15:773-784; 5 figures; 1925.

Maxton, J. L. Effect of fertilizers on the germination of seeds. Soil Science 23: 335-341; 1927.

Runnells, R. A., and Thorp, Jr., Frank. The effect of fowl typhoid vaccination upon the macroscopic agglutination test for *Salmonella pullorum* infection. Journal of the American Veterinary Medical Association 72:90-105; 1927.

Runnells, R. A., Coon, C. J., Farley, H., and Thorp, F. An application of the rapid-method agglutination test to the diagnosis of bacillary white diarrhea infection. Journal of the American Veterinary Medical Association 70 (N. S. 23):660-662; 1926-1927.

Runnells, R. A., and Van Roekel, Henry. The occurrence of white diarrhea infection in eggs laid by hens reacting to the agglutination test. Poultry Science 6:141-147; 1927.

Runnells, R. A., and Van Roekel, H. Further observations on the occurrence of white diarrhea infection in eggs laid by hens reacting to the agglutination test. Poultry Science 6:229-232; 1927.

Simpson, W. F. An economic study of methods of harvesting soybeans for seed. Journal of the American Society of Agronomy 17:557-567; 1925.

Schneiderhan, F. J. Research on fruit diseases in 1923. Proceedings of the Virginia State Horticultural Society (1924):126-136; 1924.

Schneiderhan, F. J. Rainfall in relation to ascospore discharge and infection in *Venturia inaequalis*. Phytopathology 15:56; 1925.

Schneiderhan, F. J. The seasonal development of apple scab. Phytopathology 15:57; 1925.

Schneiderhan, F. J. Cedar rust studies in 1925. Proceedings of the Virginia State Horticultural Society (1925):134-140; 1926.

Stearns, L. A., and Hough, W. S. Spreader test on apples and peaches. Journal of Economic Entomology 17:274-278; 1924.

Wingard, S. A. Yeast-spot of lima beans. Phytopathology 12:525-532; 4 figures; 1922.

Wingard, S. A. Bacterial soft-rot of tomato. Phytopathology 14:451-459; 3 figures; 1924.

Wingard, S. A., and Godkin, James. Tobacco diseases in Virginia and their control. V. P. I. Extension Division Bulletin No. 90; 31 pages, 17 figures; 1924.

Wingard, S. A. Studies on the pathogenicity, morphology, cytology of *Nematospora Phaseoli.* Bulletin Torrey Club 52:249-290; 3 plates; (Nos. 7-9); 1925.

Wingard, S. A. The immediate effect of cross-pollination on the size and shape of bean seed. Genetics 12:115-124; 3 figures; 1927.

Wolfe, T. K. Observations on the blooming of orchard grass flowers. Journal of the American Society of Agronomy 17:605-618; 1925.

Wolfe, T. K., and Kipps, M. S. Pollination studies with orchard grass. Journal of the American Society of Agronomy 17:748-752; 2 figures; 1925.

Wolfe, T. K. A mathematical inquiry into the influence of the amount and distribution of rainfall on the yield of corn. Journal of the American Society of Agronomy 17:356-362; 2 figures; 1925.

Wolfe, T. K. The effects of fertilizers on the yield and the ear characters of corn. Journal of the American Society of Agronomy 16:551-552; 1924.

Wolfe, T. K. The use of the words analysis and formula in reference to commercial fertilizers. Journal of the American Society of Agronomy 16:372-373; 1924.

Wolfe, T. K., and Kipps, M. S. The comparative value of scarified and of unhulled seed of biennial sweet clover for hay production. Journal of the American Society of Agronomy 18:1127-1129; 1926.

Wolfe, T. K., and Kipps, M. S. Further studies of the pollination of orchard grass. Journal of the American Society of Agronomy 18:1121-1127; 1926.

Wolfe, T. K. The yield of various pasture plants at different periods when harvested as pasturage and as hay. Journal of the American Society of Agronomy 18:381-384; 1926.

INVESTIGATIONS IN AGRICULTURAL CHEMISTRY

By W. B. Ellett and H. H. Hill

A sketch of the progress and results of investigations in agricultural chemistry is here given covering the period from July 1, 1919, to June 30, 1927.

Fixation of Phosphoric Acid

The original purpose of this investigation was to show: First, what becomes of the phosphoric acid from fertilizers left in the soil after the removal of the first crop; and secondly, is this an excess deposit from which the farmer draws interest or is it lost by being changed in the soil into compounds unavailable to the plant.

One of the first things attempted was a study of the power of the several general soil types found in Virginia to fix phosphoric acid in the soil as measured by fifth normal nitric acid and by Dyers' citric acid method. This study showed that there was a great variation in the soil types as to fixation, Albemarle soils fixing approximately 95 per cent. of the water-soluble phosphoric acid, while on the other hand, the soils from the Norfolk and Valley areas, only fixed about 40 per cent. These fixed forms of phosphoric acid as indicated by the solvents used, were unavailable to plants.

As a further study laboratory absorption methods were employed to determine whether the soluble phosphates when added to fixing agents found in soils were forever locked up in unavailable compounds of phosphorus. Monocalcium and acid phosphates were used in these trials and to these solutions calcium carbonate, ferric hydroxide, and aluminum hydroxide were added as the fixing agents. Availability studies were made on these compounds by using neutral ammonium citrate and fifth normal nitric acid. The results of this study have shown that the substances found in soils fixing phosphoric acid, may fix phosphoric acid from water solutions into compounds of different degrees of solubility. Hydroxides of iron and aluminum fix 60 to 70 per cent. of the water soluble phosphates into insoluble forms, or as measured by citric acid, neutral ammonium citrate and fifth normal nitric acid. The resulting combinations are more or less insoluble and would be classed as unavailable.

The effect of lime when mixed with soluble phosphates containing the fixing agents, iron and aluminum hydroxides, lessened the percentage of fixed phosphoric acid since 57 per cent. of the added phosphoric acid was available showing that a definite part of the phosphoric acid combined with

the lime. When calcium and magnesium carbonates were used as fixing agents the resulting compounds were completely dissolved and would therefore be classed as available to the plant.

A study of the solvent action of weak acids on the fixing agents found in soils showed that mono-calcium and acid phosphates were fixed by calcium carbonate because di- and tri-calcium phosphates could be detected. Iron will withdraw part of the phosphoric acid from the solutions, the remainder crystallizing out as dicalcium phosphate which was detected by micro-chemical methods.

Greenhouse studies were then undertaken to determine the availability of the fixed salts by taking plant growth as the measure, the materials used being fixed from solutions of mono-calcium phosphate and acid phosphate by calcium carbonate, iron and aluminum hydroxides. The availability was compared with acid phosphate and floats, in pots, extracted sand being used. A nutrient solid mixture of plant food was used and the phosphates from the above sources were applied. If the weight of the crop is a measure of the availability of the compounds, the soluble phosphoric acid from these two sources, when fixed by iron and aluminum and calcium carbonate, could not be classed as unavailable, as far as the wheat plant is concerned. It would appear that the wheat plant may reach further in its search for phosphoric acid than is indicated by the several solvents used to determine the available phosphoric acid in soils or fertilizers containing phosphates.

These pots were sown to oats after the removal of the wheat crop, without the addition of any phosphate material, in order to study the residual effects and to see if any of the soluble phosphoric acid remained for use by a second crop. Especially was this necessary because it was thought that the first crop removed only the available phosphates from the iron and aluminum compounds and the second crop would show the true availability of the salts fixed by the several fixing agents.

With the second crop, practically the same results were obtained as with wheat. A third series of pot studies was begun using corn as an indicator of phosphate needs. In this series the same amount of lime was added to each pot to eliminate any possible acid or toxic effects. Two crops of corn were harvested and the results obtained duplicated the original experiment, the results showing clearly that the solvents used by chemists to determine the availability of phosphoric acid do not show their true availability and can not be correlated with what the plant can or cannot assimilate. These studies were conducted in an artificial way and in a glass house which perhaps does not correspond exactly with actual conditions in the field. Therefore these experiments were repeated on four soil types in cylinders under natural conditions.

The cylinders used in a continuation of this study were of galvanized iron, 23½ inches in diameter and 4 feet deep, under-drained with 4-inch tile.

The soils used were from Albemarle, Appomattox, and Norfolk Counties. The first two types were of an old geological origin and had a very high fixing power. The latter type fixed from 40 to 50 per cent. of the phosphoric acid added. The soils in the cylinders were exhausted of phosphoric acid as much as possible before applying the fixed salts and other forms of phosphoric acid used in the experiments. The crops used for exhausting the soils were oats, sorghum, and corn. After these crops were harvested, fertilizers and fixed salts were applied and the cylinders were sown for three succeeding years to wheat, turnips, and corn.

The fixed salts of iron, aluminum, and calcium produced larger yields of wheat when applied to the Albemarle soil than did the more soluble forms of phosphoric acid represented by acid phosphate. Floats when compared with the check cylinders gave about the same results. Turnips appeared to have a greater drawing power upon the phosphoric acid from floats than any other crop grown on this soil type. Acid phosphate and the fixed forms of phosphoric acid gave about the same yields with this crop. With corn the fixed salts gave larger yields than acid phosphate.

With the Appomattox chocolate soil, the first two crops failed to give any definite results but with corn the cylinders to which the fixed salts had been added gave as good yields as the more soluble forms of phosphoric acid. With this soil type floats gave very poor yields.

On the Norfolk soil all the fixed salts with the exception of phosphoric acid fixed by calcium carbonate gave as good, if not better, yields than acid phosphate, when wheat was used an an indicator.

It was originally planned to use the Blacksburg soil in these experiments but the work of the Experiment Station has shown that on the plats at Blacksburg 200 pounds of acid phosphate per acre give the most economical results, therefore a gray type of soil from Appomattox County was substituted. This soil type had a fixing value of 58 per cent.

Light Appomattox soil gave varying results with wheat and turnips but with corn the fixed salts carrying phosphoric acid gave as good yields as acid phosphate.

The study of fixation of phosphoric acid in the soil was carried still further by the introduction of field experiments. The results given above were obtained in the laboratory, greenhouse, and by cylinder experiments. In order to determine whether these results represent in any way conditions in general farm practice, verification was attempted under field conditions. Corn was selected as the most suitable crop as soil samples could be taken throughout the growing season without injury to the crop. These experiments were begun in the spring of 1907 and are being continued at the present time under slightly modified conditions.

Soil samples were taken and analyzed monthly during the growing season for the first ten years. Fifth normal nitric acid was used to study the changes that might take place in the composition of the soil when large or small amounts of plant food were applied, so as to correlate, if possible, the amount of available plant food as measured by this solvent with the crop yield. Fifth normal nitric acid was used because it was thought that it would differentiate phosphates when in combination with different substances.

A summary of the results for the first fifteen years shows that when fifth normal nitric acid is used as a solvent, added phosphates from acid phosphate, basic slag and floats, when incorporated with the soil, could be detected, the larger the addition the greater the amount recovered. When equal amounts of phosphoric acid from these three sources were considered, the solvent extracted approximately the same amount of phosphate from the soil and if the corn crop is taken as a measure of the availability of these phosphates, about equal yields were obtained, as all the necessary plant food, including organic matter, and with the exception of lime, had been applied to the soil.

On plats that received no phosphates the amount of phosphoric acid extracted gradually dropped until the average was about 15 parts per million, which is less than one-half of the original amount found in the soil in 1907, the year the experiment was begun. This amount is insufficient to produce a yield of corn of forty bushels per acre, showing that a decrease in soluble phosphoric acid as shown by the solvent is an indication of a material decrease in available phosphates. The crop yields on the plats receiving no phosphates decreased enormously and plant growth was materially stunted, showing clearly the need of phsophorus on these plats.

The amount of phosphoric acid rendered available by the weathering agencies in the soil from year to year amounts to about 15 parts per million each year. This is sufficient to produce on this type of soil only about 15 to 20 bushels of corn per acre, and this is about the present yield. How long this condition will remain is impossible to predict but it seems that these plats receiving no phosphates are materially diminishing in yield with each harvest.

Where 600 to 400 and 200 pounds of acid phosphate or their equivalent in Thomas slag and floats were added no appreciable increase in yield was noted, showing that the equivalent amount of phosphoric acid from either of these sources is sufficient for maximum yields on this soil type provided that the other plant food elements and other soil conditions are fulfilled.

A complete fertilizer containing 200 pounds of acid phosphate has given slight increases in yield on the basis of a 15-year average. Where 10 tons of stable manure were used the average yield has increased from 40 to 66 bushels per acre. On Plat 18, receiving 1,200 pounds of burnt lime per acre annually the amount of phosphoric acid extracted has decreased through the 15-year period but the yield of corn has been maintained at the original average and

in some years materially increased. This plat has given material for studies on the nitrogen content of the soil, as well as for a study of the effect of the added lime on the lime-magnesia ratio of the plats over long periods. These plats have also furnished information leading to studies concerning the ripening period of corn as affected by fertilizers as well as the influences on plant diseases, plant composition, and related studies. There is now under investigation a study of the effect of long applications of single fertilizers on the composition and nutritive value of the crop grown.

The Leaching of Plant Food Through the Soil

Lysimeter equipment was installed in 1922 to measure the income and outgo of the plant food of the soil. This is measured by analyzing the leachings that pass through known depths and areas of soil in separate tanks, the area of which is known. Similar tanks are used for control purposes to catch the rain and snowfall and allow it to pass into receptacles similar to those employed for catching the leachings from the soil.

The equipment consists of a concrete cellar surrounded by 92 tanks constructed so that the drainage from each tank can pass through the concrete wall in block tin tubes into receptacles located inside the cellar. The plant is located on a terrace which is of advantage in the disposal of waste water and allows an easy entrance into the cellar. The inside dimensions of the cellar are as follows: Length, 43 feet; width, 7 feet; and height, 7 feet.

The walls are constructed of reinforced concrete 9 inches thick at the base and 6 inches at the top. The roof is slightly arched and constructed of reinforced concrete 5 inches thick. On the ends and sides of the inside walls of the cellar two tiers of heavy oak platforms are placed to hold the drainage water receptacles. The receptacles for holding the leachings are made of heavy galvanized iron and have a top through which the leachings pass and which is removable so that the samples can be weighed accurately by placing the receptacles on a balance kept in the cellar for that purpose.

The soil tanks are made of heavy Toncan iron, the bottoms having an opening one-half inch in diameter to which the block tin tubes are soldered. This opening is covered by a fine wire screen and over this, covering the bottom, the tanks have several layers of quartz pebbles, which act as a filter and prevent the soil from passing through the tanks into the receptacles which catch the leachings. The tanks vary in depth; however, most of them are only 12 inches deep. These one-foot tanks contain 8 inches of soil, the weight and area of which are known. Some of the tanks are 2 feet deep. In these, 12 inches of subsoil have been placed and over this 8 inches of soil. Some of the other tanks are 4 feet deep and have 36 inches of subsoil and 8 inches of soil. The different depths were installed so that the amount of plant food lost by leaching could be determined under varying conditions. The soil and subsoil were

taken from the field and an effort was made to place them in the tanks in the same relative position which they occupied in the field. Two types of soil were selected for the studies. In 62 tanks soil and subsoil taken from the college grounds were used. This soil is typical of the limestone soils found in the Valley and Southwest Virginia.

Through this line of investigation it is expected that further facts will be learned as to what becomes of some of the plant food elements when they are applied to soils.

Some of the questions asked the chemist are: What form of lime is the most available? How often should lime be applied? How much of it is leached through or carried far into the subsoil, thus becoming unavailable to plants grown on the soil?

To answer these and other questions, lime from different sources has been applied. To some of the tanks the lime application was made when the tanks were filled. To others one-fourth of the application is made annually. This will show the effect of small applications frequently applied. Still others have the lime mixed in the upper three inches of soil; and finally in some the lime is incorporated with all of the soil. However, the main problems of study for which the lysimeters were installed have to do with the amount of nitrogen, lime, and sulphur leached from the different types of soil and the effect of turning under large amounts of organic matter on the solubility of plant food compounds as measured by the amount of these elements in the leachings. The two rain gauges show the amount of water from snow and rain and this is carefully weighed and samples of it are analyzed. By this means the amount of nitrogen, sulphur, potash, and lime brought to the soil from the atmosphere is determined. By these methods a complete account of the income and outgo of the plant food will be obtained.

The results for three years show the average per acre per year gain through atmospheric agencies to be 3.78 pounds of nitrogen; 37.0 pounds of calcium, calculated as carbonate; and 13.19 pounds of sulphur. The average per acre per year loss from the soil by leaching was 46.12 pounds of nitrogen; 166.87 pounds of calcium, calculated as carbonate; and 15.01 pounds of sulphur.

During the year 1924-1925 this department supplemented the equipment for lysimeter studies. We are cooperating with the Tennessee Agricultural Experiment Station on studies of the movement of lime through the soil when applied to different types of soil. Thirty-one new soil tanks have been installed. In 30 of these tanks soil was used from the branch experiment station at Holland, Va. This is a sandy type of soil representing the Norfolk sands. The lime applications made were as follows: Burnt high calcium lime, limestone, dolomite, and dicalcium silicate. Some of the tanks have an annual application, and others have an application once in four years. In others the

lime was incorporated with the soil and in others it was mixed with the top three inches. The Tennessee Experiment Station has installed similar equipment but the type of soil is different. The lime applications are the same. The results of the work from the two stations will be available to Tennessee and Virginia jointly.

Spray Residue on Apples

The object of a series of experiments started in 1926 was to determine the amount of arsenic remaining on apples and foliage when the spray recommendations calling for arsenicals were used and to suggest methods for its removal from the fruit. The apple crop is important in Virginia. Lead arsenate and other arsenicals are used to kill the biting types of insects, which if not killed do great injury to the market value and yield of apples.

Commercially grown apples were analyzed and the amount of arsenic remaining on the fruit was determined. On some of the varieties examined the amount of arsenic found would prohibit their shipment in inter-state traffic and from the work done it seems imperative that some method for the removal of arsenic should be used. Mechanical and chemical methods were studied and our work shows that wiping and brushing methods are unsatisfactory. The arsenic can be removed by dipping the fruit in a 2.5 per cent. solution of hydrochloric acid at ordinary temperature. This apparently leaves no taste or injury either after washing in water or after leaving the fruit to dry. Storage experiments conducted also show that the keeping qualities of the apples treated with hydrochloric acid were not injured but probably enhanced.

The Chemical Department has also determined the arsenic by analyzing the foliage of apple trees when different arsenicals were used as sprays in an effort to determine their sticking qualities. This part of the work was done in cooperation with the Department of Entomology and we have also analyzed the caterpillars feeding on the foliage to see how much arsenic from the different arsenicals was required as a lethal dose and the time required to kill the insects.

Green Manure Project

It has been our object since the inception of this project to develop the work on this problem in a logical manner, taking a small portion at a time and working it out thoroughly. At the present time papers have been published on methods of attack, nitrate formation, acidity and rapidity of decomposition as evidenced by carbon dioxide evolution.

The work on methods showed that the shorter colorimetric procedure for the determination of the soluble nitrogen developed in the soil after treating with organic matter was just as accurate for the work in hand as the longer

reduction methods. Virginia soils were found to be very deficient in nitrate nitrogen, the average amount in every 100 grams of dry soil being about 1 milligram. The colorimetric method for nitrates gave excellent results on these soils and it was thought expedient to use this method whenever possible on account of its rapidity.

The work on nitrification of green manures was very elaborately planned and embraced soils from each of the four great physiographical divisions of the state. The work involved both chemistry and bacteriology. It developed that legumes not only increased bacterial numbers over a non-legume treatment but gave much greater increases in soluble nitrogen and plant growth. Pure cellulose gave a depressing effect on bacterial count, nitrates and plant growth. The soil recuperated from these ill effects after 12 months, however, and normal nitrification proceeded. This peculiar behavior of pure cellulose has caused widespread comment among soil investigators. This department put forth the idea from the results of experimentation that the organisms which decompose the cellulose make use of the nitrates of the soil for the development of cell protoplasm, the dead cells later being nitrified in the soil. This is the accepted theory today among soil scientists and unpublished results will further support this theory. It was proved that in every case plant growth was benefited by the addition of green manures. The expermients further showed that soils vary in their power to accumulate nitrate nitrogen. Soil from the same field, when taken at different periods, shows a variation in nitrogen accumulating power.

This paper was one of the first extensive pieces of work on green manuring in this country and the results have been widely commented upon by soil investigators and text book writers on agricultural subjects. In commenting on these findings Waksman (Principles of Soil Microbiology, Williams and Wilkins, Baltimore, Md., 1927, pp. 706-707), says, "these results point to the practical conclusion that whenever a readily available source of nitrogen is wanted immediately, substances containing less than 2 per cent. nitrogen cannot be profitably used. The greater the nitrogen content of the material, the greater is its value as an immediate source of nitrogen." Greaves, in his work on Agricultural Bacteriology, and Lyon and Buckman, in their work on soils, and Hinkle have commented favorably on this work.

This department was the first to advance the idea that the turning under of green crops did not produce acidity in soils as has been thought since early times. This theory was revolutionary at the time but it is now generally accepted by soil scientists after repeated duplication of our results. We have reasoned that the ash of plants is alkaline and on decomposition exerts a marked influence in correcting soil acidity resulting from the incorporation of green crops with the soil. The results secured in the field showed any acidity to be of a transitory nature and in many cases an alkaline reaction was

shown. This is the generally accepted theory today. Quoting this work, Pieters in his recent book on Green Manuring (John Wiley and Sons, 1927, New York) says, "the results of experimental work on the acidity produced by green manures prove that green manures do not increase soil acidity or, if so, that such a condition is transitory."

The latest paper published on green manuring concerns itself with the rate of decomposition of organic matter in the soil as evidenced by the rate of carbon dioxide evolution. The results secured are in the paragraphs which follow.

Pure cellulose applied to soils in different amounts restricted plant growth. This restriction was proportional to the amount of cellulose added. The addition of postassium nitrate in quantities of about 0.01 per cent. failed to offset this harmful effect of the cellulose. Varying the quantity of nitrate had very little effect in counteracting the ill effects of the cellulose, beyond an eight-ton application. Plants when grown in a well balanced nutrient solution were healthy and vigorous but the addition of cellulose depressed plant growth. Conditions were improved slightly by renewing the nutrient medium frequently. The depression in plant growth was proportional to the amount of cellulose added.

Decomposing cellulose produced hydrogen sulphide as a reduction product of the sulphates of calcium and magnesium contained in the nutrient solution.

The root systems of the plants were altered materially by a cellulose treatment, the roots becoming very much discolored and altogether unhealthy in appearance.

Crimson clover when added to sand and to Hagerstown silt loam soil in tubs and allowed to remain out of doors gave increased plant growth.

With four leading Virginia soil types in tubs out of doors, rye in a green state depressed plant growth in the heavy clay types of soil. In the more open types of soil a slight increase in growth was noted.

Corn grown in the field where clover was turned under gave an increased yield over corn with the clover removed for hay.

Corn was depressed in yield where rye was turned under over a period of 12 years.

Wheat grown where soybeans were cut for hay gave a much smaller yield than wheat which had soybeans turned under as a green manure.

Wheat yields were slightly increased by the turning under of buckwheat. There was a depression of yield when buckwheat was removed for hay.

Rye, oats, clover, and vetch show a varied ratio between their nitrogen and carbon when cut on May 17. The ratio between the nitrogen and carbon is much wider for the non-legumes than for the legumes.

The evolution of carbon dioxide from rye, oats, clover, and vetch, cut on May 17 and mixed with soil was much greater than from the same materials which had been allowed to air-dry for the same period of time. The legumes showed a more rapid decomposition in every case than did the non-legumes.

When green materials were allowed to decompose in the soil no nitrates were detected after the experiment had been run for 10 days. With the same substances that had been allowed to air-dry, nitrates were present but in much greater quantity under a legume than under a non-legume treatment.

Drying green manures retards their decomposition when gauged by carbon dioxide liberation over a 10-day period. This retardation in decomposition may probably be due to the soluble hemicelluloses and other polysaccharides having been changed to less soluble forms.

Rye, oats, clover, and vetch cut at different stages of development show wide differences in their nitrogen-carbon ratio. The younger the cutting the narrower the ratio. The ratio between these two elements widens as the plant approaches maturity. Vetch gave a much narrower ratio than any of the other crops studied.

Carbon dioxide liberation from green manures cut at different stages of growth showed a rapidity of decomposition in the following order: Vetch, clover, oats, and rye. Green manure cut between May 14 and May 28 showed the highest rate of decomposition. With cellulose in a pure form the decomposition was very slow. There was a fairly good nitrification with legume treatments but with non-legumes the nitrates formed were in much smaller amount.

Waksman (Soil Science 24:318-319, 1927), after confirming certain portions of this investigation, says, "By determining the CO_2 evolution as an index of decomposition . . . demonstrated that not only do plants decompose more rapidly at an early stage of growth but there is a definite relation between the nitrogen content of the plant and its decomposition; the higher the nitrogen content the more rapidly does the plant decompose, since the percentage of nitrogen in the plant diminishes with the advance in growth and its rate of decomposition also diminishes. Since legumes contain more nitrogen than non-legumes, they decompose more rapidly. Drying of the green plants was found to retard the decomposition of the plant; the assumption was that, as the result of drying, soluble hemicelluloses change into less soluble forms."

The work under way on green manures at this time concerns the carbohydrate content of certain organic materials and the changes affecting the soil nitrates. This work has a direct bearing on the peculiar reducing effect of cellulose noted in earlier experiments with green manures. The results to be obtained should have a direct bearing on the fertilization of apple orchards.

Investigations planned involve the action of organic matter as a mulch and its effects when incorporated in the soil as measured by lysimeter leachings.

Sulphur and Rock Phosphate in Compost

In November, 1917, the National Research Council, Council of National Defense, called a meeting of agricultural workers to consider investigations relative to means of increasing the availability of the phosphorus in rock phosphate, which could be used as a substitute for acid phosphate.

The primary object of the investigation was to determine the changes that would take place when phosphate rock was composted with soil, sulphur, and manure. The results secured from this investigation follow:

The addition of sulphur to a compost of soil and rock phosphate increased the availability of phosphoric acid, but not to the same extent as when manure was added to a compost of soil, rock phosphate, and sulphur.

In composts without sulphur no appreciable increase in the availability of phosphoric acid was noted.

Sulphur oxidation preceded the increase of available phosphoric acid.

The addition of phosphate to manure slowed up fermentation and there was a loss of only 57.80 per cent. of dry matter and 48.21 per cent. of nitrogen in two years. At the same time there was an increase of 0.138 pound of nitrate nitrogen and a loss of 0.031 pound of ammoniacal nitrogen.

The addition of sulphur and phosphate to manure checked the fermentation to a greater extent than the phosphate alone. There was a loss of only 43.77 per cent. of dry matter and 46.44 per cent. of nitrogen in two years. But here the increase in ammoniacal nitrogen was balanced by the loss in the nitrate nitrogen.

Upon the addition of rock phosphate to manure a large quantity of nitrate nitrogen was formed. When sulphur was also added there was no nitrate formation but the ammonia content was greatly increased.

All of the Virginia soils tested had some sulfofying power, but there was a very great variation among the different soils.

The majority of the Virginia soils oxidized less sulphur than the soils tested by Shedd of Kentucky and Brown and Kellogg of Iowa.

The results of composting soils, sulphur, ground phosphate rock, and manure, under the conditions suggested by the plan as outlined, do not in our opinion warrant the farmers of Virginia conducting experiments along similar lines, because the formation of available phosphoric acid is too slow to meet their needs. Besides, the farmer cannot be expected to keep the water-holding capacity of his compost up to the desired amount, and he is not likely to spade the compost every 10 or more days so that the proper oxidation would occur. Probably some conditions might arise or different proportions of soil, rock phosphate, and sulphur be suggested, or a better starter or inoculating material might be used, which would give higher sulphur oxidation and thereby produce more available phosphoric acid than is possible under the conditions which obtained in the experiment.

Miscellaneous and Cooperative Experiments

The fixation project has enabled us to publish papers on chemical studies of Virginia soils and fixation of phosphoric acid by bases found in soils. This work brought out the fact that the so-called available phosphoric acid is a rather relative term.

Referring to this work Waggaman and Easterwood, in their American Chemical Society Monograph, issued in 1927, say: "While attempts have been made to measure the availability of such phosphates by their solubility in certain weak acids and dilute solutions, no satisfactory laboratory methods have yet been devised which will accurately determine the rate at which these phosphates dissolve in the soil solution or give a true index of their effectiveness under soil conditions."

These experiments have enabled the department to show that applications of large quantities of superphosphate will not increase soil acidity. This fact has been brought out in department publications.

Our work has definitely proved that applications of caustic lime do not burn out the organic matter of soils, nor do such applications decrease the percentage of nitrogen.

The plats used under the fixation project have afforded means for studying the effects of fertilizers on the winter killing of wheat and also the effect of fertilizers on the marketability of corn produced over a period of years.

These plats have furnished material for a study of the lime-magnesia ratio of soils under continuous cultivation. A publication issued in 1922 showed the plats to be very deficient in lime and in many cases the base magnesia was in excess. That continued cropping had diminished the lime and relatively increased the magnesia is evident from the results presented and a restoration of the lime had to be made before beneficial results could be obtained from the application of commercial fertilizers.

This plan was adopted, keeping one-half of each plat under its original treatment and liming the other. Increased yields on all plats have been noted since this change was made.

This department has cooperated with the Association of Official Agricultural Chemists on methods for the determination of borax in mixed fertilizers. Just after the beginning of the World War very little potash was brought into this country from France and Germany for use in fertilizer manufacture, and fertilizer dealers were unable to fill their orders from these sources. The principal sources of potash salts at that time were the Chilean and Searles Lake (California) deposits. The Bureau of Soils of the United States Department of Agriculture investigated these sources of potash and recommended their use under certain limitations. Furthermore, Congress had encouraged the production of potash from domestic sources, but unfortunately these mate-

rials contained borax in varying quantities which might restrict their use to a more or less extent. This department investigated two of the leading methods for the determination of borax in fertilizers and reported the results in a paper appearing in the annual report of this Station for the period 1918-1919.

This department also cooperated with the Thomas Slag Phosphate Committee of the Association of Official Agricultural Chemists to determine primarily the availability of phosphoric acid in Thomas Slag phosphates in comparison with other phosphates. The availability was measured by comparison between the yields secured where four such phosphates were used, and those obtained from the use of ground blue phosphate rock, acid phosphate, sodium phosphate, and double superphosphate. The results of this investigation are found in Technical Bulletin 16.

The Chemical Department has always cooperated with the other departments of the station. A great amount of time has been spent in making analyses for the departments of agronomy, plant pathology, horticulture, and entomology. The projects of the departments of chemistry and dairy husbandry have required practically all of the time of at least one member of the department. A report on this phase of the work is presented by C. W. Holdaway, head of the department of dairy husbandry.

PROGRESS AND RESULTS OF INVESTIGATIONS IN PLANT PATHOLOGY

By F. D. Fromme

This report gives a running sketch of the progress and results of experimental work in plant pathology for the period from July 1, 1919, to June 30, 1927. The several lines of investigation are dealt with under the project titles.

Black Rootrot of Apple

This project which has been active since 1915 has been concerned primarily with the determination of the causative agent in the black rootrot disease of apple, and with studies of the occurrence of the disease in relation to such factors as soil type, apple varieties, orchard practices, and other factors which might bear on problems of occurrence. Considerable study has been devoted to the problem of control and this has been prosecuted chiefly as a study of the susceptibility of root stocks, in the hope that resistant varieties might be isolated.

Prior to 1919 the cause of the disease was determined as an Ascomycetous fungus, a species of Xylaria. Later work has established the correctness of this in ample detail. Until recently the assignment of the species has been in doubt. There is much confusion as to the proper use of names of species of Xylaria. There seems little doubt that the species in question has usually been designated *Xylaria digitata* in America, but this name is properly referred to a European species which is distinct from the American form. The writer has renamed and described the American species as *X. mali.*

The disease has been studied as to occurrence throughout the State. It is especially prevalent in the Shenandoah Valley and in localities in the Piedmont section. It has also been demonstrated to occur in a number of other states. West Virginia appears to mark the northern limit of distribution, South Carolina the southern limit, and Arkansas the western limit. This disease is the most important single cause of apple tree death in Virginia. It occurs in more than half of the orchards of the Valley section and the average loss of trees is 18 per cent. at 21 years of age. It is even more destructive in certain orchards. Detailed studies of incidence and duration of disease, fruiting of the pathogen, and of the history of replanting have been made. Few trees set as replants in infested orchards attain bearing age.

It has been shown in studies conducted during the years 1922 to 1927 that the fungus is capable of attacking the following trees in addition to apple:

Mahaleb cherry, *Pyrus communis, P. ussuriensis,* elm, honey locust, and Norway maple. There was no infection of ash, black locust, box elder, butternut, chestnut, silver maple, or black walnut.

A considerable study of susceptibility of the scion roots of certain varieties of apple has been made. In preliminary tests in 1917 it was indicated that scion roots of the Northern Spy variety might have appreciable resistance and additional tests were made at Crozet from 1919 to 1922. The Spy roots in these tests showed appreciable resistance as compared with seedling roots. The latter developed 78 per cent. of infection while Spy roots developed only 17 per cent. In additional tests made at Blacksburg, 1922-1927, French apple seedlings developed 45 per cent. infection, American apple seedlings 36 per cent., and scion roots on Northern Spy only 4 per cent. A considerable number of varieties of scion roots, 29 in all, were tested in 1926-1927 at Staunton, Virginia. Infection developed to some degree in all varieties.

In addition to the inoculation tests, Spy roots have been used for replanting in two orchards where black rootrot has been especially prevalent. They were planted in 1919 and by 1927 the losses have ranged from 30 per cent. in one orchard to 80 per cent. in the other. It seems evident from these results that while the Spy root may be superior in resistance to the average of seedling roots, it is not sufficiently immune to warrant its use in severely infested soil.

Studies of the susceptibility of seedlings grown from open pollinated fruits of standard apple varieties have been conducted with ten varieties in 1925, twenty-five varieties in 1926, and thirty-five varieties in 1927. The planting of 1927 included two thousand individuals. In these tests there has been no variety which has been consistently immune. It is true that certain varieties have consistently shown greater susceptibility than others but it does not appear probable that any one variety is sufficiently uniform in its resistance to warrant its selection from this standpoint. It appears true that resistance is more apt to be a property of individuals rather than of varieties and with this in mind additional tests of those individuals which have escaped infection in previous tests and which have root systems of a desirable type are under way. It is planned to continue such elimination tests on these individuals until their resistance or susceptibility has been fully demonstrated. If resistant individuals are isolated they will be propagated asexually and may be used as foundation stocks for use in orchards where rootrot is prevalent.

Studies of Bean Rust

In previous studies of the rust disease of beans we have determined the relative susceptibility of a large number of varieties of kidney beans and have published the results in Bulletin 220 of the Experiment Station and also in a more technical paper in Vol. 21:385-404, in the Journal of Agricultural Research. Recently studies have been concerned especially with the genetics of

rust resistance and with attempts to isolate resistant lines from the progeny of crosses. Two of the most popular varieties, Navy Pea, which is used as a dry bean, and Kentucky Wonder, used as a snap, are very susceptible to rust. We have attempted to secure resistant hybrids of these types through crosses with resistant varieties. Hybrids of other varieties have also been studied.

It has been true in all of these crosses that rust resistance is exhibited as a dominant unit factor. The F_1 generation of all crosses has been uniformly resistant and identical with the resistant plant in this respect. Segregation has occurred in the second generation and resistant and susceptible lines have occurred in a close approximation to the 3:1 ratio. The genetics of seed color and of other characters is not, however, so simple a matter and isolation of resistant lines of the desired types has involved the purification of some of the original families secured in the F_2 generation through a number of additional generations. The original cross of Navy Pea and Improved Goddard was made in 1918 and successive generations have been grown in each succeeding year. Some of the selections now appear to be quite fixed in their resistance to rust and they are scarcely distinguishable from the Navy Pea variety in other respects. The best of these are being tested as to yield and they are also being distributed to a few farmers for limited tests.

Kentucky Wonder was hybridized with two varieties, Brockton and Marblehead, in 1922 and isolations from these crosses have been studied in each successive year. Some of the selections are quite good as to quality and are like the Kentucky Wonder parent in habit but are not as yet fully fixed as to their resistance. It is believed that the desired type will be obtained in another year or two of selection.

One very interesting result of the study has been a pronounced effect on the size of the seed produced in one series of crosses as an immediate effect of hybridization. This occurred in crosses of Powell's Prolific, a variety with small seed, and Marblehead, a variety with large seed, and occurred only when the former was used as the pollen parent. It did not occur in reciprocal crosses. The seed produced from this cross showed an average increase in weight of 55 per cent. over that of the seed parent and an increase of 156 per cent. over that of the pollen parent. The average depth of the seed was 10 per cent. greater, the average width 14 per cent. greater, and the average length 31 per cent. greater, than the corresponding average dimensions of seed of the maternal parent. Details have been published by Doctor S. A. Wingard in Vol. 12: 115-124, of Genetics.

Another interesting development of the study has been the discovery of the specific identity of rust of cowpeas. This species has formerly been considered identical with rust of beans, but has now been shown to be not only distinct in its host ranges but also in morphological characters. It is properly designated as *Uromyces vignae*. In our inoculation tests which included most of the

varieties of cowpeas commonly cultivated in America, it developed normally only on the Black-eye variety and on strains of this variety. A study of herbarium specimens indicates that the species also occurs on three additional species of Vigna, one of Dolichos, and one of Phaseolus. A technical paper dealing with this study was published in Phytopathology, Vol. 14:67-79.

Tobacco Blackfire

The blackfire disease of tobacco which first attracted our attention in 1917 was demonstrated to be caused by a parasitic species of bacterium which was described by us in a technical paper in the Journal of Agricultural Research, Vol. 16:219-228, as *Bacterium angulatum*. Beginning in 1919 and for three succeeding years, our attention was given especially to a study of field aspects of the problem. After extended field study the conclusion was reached that infection in the tobacco field results largely, if not entirely, from the setting of infected plants from the plant bed. Study of the possible sources of introduction of disease into the plant bed indicated three sources as the most important factors. These are: the seed, the cloth used as the plant bed cover, and tobacco refuse such as stalks or leaf refuse applied as fertilizer on the plant bed or left on or in the soil of the bed when it is used for two successive years. Methods of disinfecting tobacco seed and of sterilizing plant bed cloth were devoloped. In the test of the efficiency of seed disinfection 90 distinct lots were treated and sown, together with corresponding untreated lots. Infection developed in 23 of the untreated lots and all of the treated lots were free from infection. In order to obtain further data as to the efficiency of seed disinfection as applied to the problem some two thousand lots of seed were treated for farmers and a number of plant beds seeded with these lots were inspected, together with beds sown from untreated seed in the same localities. The treatment reduced infection in the plant beds to a marked degree and the general introduction of this practice, together with other sanitary measures that were indicated, appears to have reduced the problem of blackfire from one of general major importance to a local problem. In the year 1920 the blackfire disease occurred in 80 per cent. of the fields in Virginia visited in that year and the average loss was estimated at 25 per cent. There has been no evidences of the disease within the past four years and although it still exists sporadically and is destructive in occasional fields, it is no longer a matter of widespread concern.

It has been further determined that dissemination in the field is accomplished chiefly by the splashing and blowing of raindrops; that fertilizers which promote the best growth of tobacco also favor the development of disease. The organism is evidently dependent for vigorous growth on a vigorous and well-nourished host.

Studies of the susceptibility of the varieties of tobacco commonly grown in Virginia, together with a number of taxonomic varieties of cultivated tobacco, indicate that all are susceptible in some degree. The majority of species of Nicotiana are also susceptible, but *N. rustica* and its varieties are practically immune. This is true likewise of a few additional species which have no economic importance. The work reported above has been published in part in Technical Bulletin 25 and later features are to be prepared for publication in the near future.

Ringspot of Tobacco

This disease which was first observed by us in 1917 has become rather prevalent of late in tobacco fields in Virginia. Active study was begun in 1925 and the disease was demonstrated to be highly infectious when leaves of healthy plants are swabbed with sap that has been expressed from diseased leaves. Infection has also been obtained through needle punctures, injections with a syringe, grafting, approach grafting, and by insect transference. Repeated attempts to isolate an organism from affected tissue have been uniformly unsuccessful. A variety of media and both aerobic and anaerobic culture methods have been employed. The disease is to be considered as one of the virus group. It has distinct properties in that it is short-lived in the expressed sap. Such sap, when exposed at room temperature, does not retain its virulence more than twenty-four hours but longevity may be greatly increased by cold storage. Material held at —7° C. has retained its virulence more than two months.

Considerable study of the susceptibility of a wide range of plants has been made and infection has now been demonstrated to occur in 37 genera of plants which are distributed among 17 distinct families. Included in the host range are such economic plants as egg plant, squash and other cucurbits, beets, beans, okra, sunflower, and castor oil plants; also such common weeds as horse nettle, ground cherry, poke weed, and jimson weed. A number of ornamental flowering plants are also parasitized. We have not as yet found ringspot occuring in nature on any host other than tobacco but it is believed that more careful search, especially in the vicinity of tobacco fields and plant beds, will reveal its presence on some of the native plants or introduced weeds. The nature of the virus would suggest that it must overwinter in perennial or biennial plants.

Loose Smut of Wheat

Studies of certain phases of the modified hot water treatment of wheat for the control of loose smut were undertaken in order to obtain more exact information. It was found that a minimum pre-soak of four hours prior to treatment is essential for the complete elimination of infection. It was further de-

termined that the grain need not stand in water throughout this period. Equally effective results are secured when the grain stands for one hour in water and is then held three additional hours in the wet sack prior to treatment. This is a consideration of some importance where facilities for soaking grain are limited.

Information as to the character of the hot water treatment was also obtained. It has been found in the past that the treatment is a selective one in that it destroys the smut mycelium within the grain without injury to the grain itself. The pre-soak treatment was supposed to activate the dormant mycelium and render it more susceptible to injury by temperature. Our studies indicate that this is not the proper explanation. In reality, the germinative ability of the infected grain is destroyed. Non-infected grains are not injured by the treatment and as a result the crop produced is free from smut.

In surveys of wheat fields conducted in 1921 a striking difference in the incidence of loose smut in two varieties of wheat was observed. Practically all fields of the Leap variety were smut free, or nearly so; while all fields of Stoner were infected, some to an appreciable degree. There were no existing data as to the susceptibility of wheat varieties to loose smut and a study of this phase of the problem was, therefore, undertaken. It was not known whether the apparent difference in susceptibility was due to fundamental inherent differences or to characteristics of the varieties which might aid or hinder infection. With this in mind, heads of the Stoner and Leap varieties were inoculated in the blooming stage with the result that Stoner developed 62 per cent. of infected plants and Leap only 4 per cent.

Further studies were then undertaken to determine the relative susceptibility of a number of pure line selections of the Fulcaster variety which had been developed by the department of agronomy. Some of these have been issued to the Crop Improvement Association and are grown on an extensive scale in the State. While not high in susceptibility, they develop enough loose smut so that seed treatment is necessary to meet the requirements for certification. Our studies indicate that these selections consist of a number of lines with reference to susceptibility. They are not pure lines from this standpoint, but they contain strains which appear to have almost complete immunity. Some of these have been isolated and have undergone three series of inoculations without developing infection. The best of these will be used as foundation stocks for smut resistant varieties. Similar resistant selections of the Poole and Fultz varieties have also been developed.

Study of the relation of soil fertility and development of loose smut has developed the fact that the percentage of infected heads is lowest in good soil and highest in poor soil. The infected plant produces more than one stool in good soil and many of the secondary stools bear sound heads. This conclusion has been confirmed both in field and greenhouse studies.

Black Stem Rust of Wheat

A very close correlation between the presence of plants of the native barberry, *Berberis canadensis*, and the occurrence of the black stem rust of wheat has been observed in certain localities in Southwest Virginia. Wheat fields near barberries invariably suffer severe injury while those remote from barberries escape with little or no infection. Local eradication of barberries has given effective control when done thoroughly over a sufficient area. Effective results were obtained with common salt applied at the rate of one-half pound per square foot of soil. Sodium arsenite and kerosene also proved effective.

Tomato Diseases

A Bordeaux mixture to which resin fish oil soap was added as a sticker and spreader gave very effective control of Septoria leaf blight of tomatoes in spraying experiments conducted over a peroid of several years. Increases in yield ranged from 34 bushels to 125 bushels per acre, the average being 76 bushels, a percentage increase of 65 per cent. The material also gave satisfactory control of the late blight disease, as did likewise a copper-lime mixture applied as a dust.

Orchard Dusting Experiments

Rather extensive dusting experiments were conducted during 1919 and 1920 in peach and apple orchards. Sulfur dusts were found to be quite satisfactory for the control of peach diseases and the practice may be recommended as the practical equivalent of spraying. The dusting method is not, however, so effective for apple diseases. Control of bitter rot was not at all satisfactory and scab was found to be more difficult to control by dusting, especially in epidemic years. Complete data were published in Bulletin 224.

Cabbage "Yellows"

In a test of two "yellows" resistant varieties of cabbage in Wythe County their marked superiority was fully demonstrated. Two commercially non-resistant varieties produced only 3 and 2 tons per acre. Selections of certain resistant individuals of the varieties All Head Early and Copenhagen were made and these have been propagated and further selected by the Wisconsin Agricultural Experiment Station. As a result, resistant varieties are now available to the growers.

Yeast Spot of Lima Beans

A new disease of the Lima bean was brought to our attention in 1921 from growers in eastern Virginia which was found on investigation to be caused by a yeast-like fungus which was later described as a new species, *Nematos-*

pora phaseoli, by Doctor S. A. Wingard. This is the species of the genus to be described and all three are parasitic on plants. Infection in the field results from the feeding punctures of the green soldier-bug which attacks the pods when young. The fungus is transferred from diseased to healthy plants in this manner. The disease has likewise been shown to occur on kidney beans and cowpeas.

Soft Rot of Tomato

A soft rot of tomato fruits which is common in Virginia and is frequently quite destructive was proved to be caused by *Bacillus aroideae.* This species has formerly been considered identical with *B. carotovorus,* the common soft rot organism, but the two were shown to be distinct in the production of acid and gas in certain media and they are also distinct in their host preferences. The former species infects kohl-rabi, tobacco, and calla lily and does not infect iris; the latter species attacks iris but none of the three other plants named. A number of additional plants are hosts for both organisms.

Seed Disinfection

Studies of seed disinfection for the control of smut diseases of oats and wheat have been prosecuted over a period of five years. The tests have especially involved materials applied as dusts and a number of the organic mercury compounds. None of the materials proved as effective for the smuts of oats as the formaldehyde treatment. The dusts were especially ineffective. The dusting method gave excellent control of stinking smut of wheat, copper carbonate being especially effective. The material is cheap and is easily applied and its use is coming into rapid favor with the farmers of the State. Interesting results were obtained with washing of wheat under a stream of water. The reduction in stinking smut infection obtained in this manner was almost as great as that obtained with chemical disinfectants. The washing need not be continued more than 30 minutes. None of the chemical disinfectants proved effective for the wheat nematode disease.

Fruit Disease Studies

The establishment of field laboratories at Winchester in 1922 and at Crozet and Staunton in 1923 gave a marked impetus to the study of fruit diseases. A considerable volume of data has been accumulated and made available to fruit growers. The more important results will be discussed under separate diseases in the following.

Apple Scab.—Studies were planned to determine the efficiency of sprays applied on a fixed schedule or calendar. Studies of spore dissemination and complete weather records were obtained in order to facilitate the interpretation

of the spraying experiments. Six years data on ascospore discharges have been obtained at Winchester and supplementary studies have been made at Crozet and Staunton. These are the most complete records that have been assembled. The discharge of ascospores varies according to seasonal conditions and is determined by rainfall. The earliest date recorded at Winchester was April 1 and the latest July 30. In the average season the limiting dates are April 15 and June 15. The number of spore discharges per season has ranged from 9 to 16. There is no fixed correlation between spore discharges and bud development. Early discharges may precede or follow the pink stage of blossoms. Those that precede the pink stage are relatively unimportant, and the most important discharges are intercepted and nullified by the pink and petal-fall sprays. The full program of sprays applied on a fixed schedule has given effective control over a wide range of seasonal conditions. The thorough application of sprays is essential to effective control. Attempts to reduce scab infection by spraying overwintering leaves on the orchard floor with lime-sulfur and oils gave little or no benefit. Bulletins 236 and 245 give more complete details of the work.

Bitter Rot.—Studies of the bitter rot disease of apple have been an important feature of the work at Crozet and have been supplemented by studies at Winchester. It has been shown that mummied fruits which remain on trees from the previous season are most important sources of infection. They appear to be the sole source in the Albemarle Pippin variety but in the Smokehouse variety the inoculum may be carried over in cankers on small twigs as well as in mummies. Mummies may retain their ability to produce spores for two years. Effective and economical control of bitter rot in Pippin orchards has been obtained by removal of mummies and the first infected fruits of the season. The spores of bitter rot have been shown to be capable of germination within 2½ hours after moistening, and the infection of apples may be beyond the reach of fungicides within 5 or 6 hours after the spores reach the fruit. Studies of bitter rot have been published in Bulletin 254.

Apple Blotch.—A method of studying the periodicity of the exudation of spores from cankered twigs by means of traps has been developed. The number of spore exudations has varied from season to season according to rainfall, the minimum number being 5 and the maximum 9. The earliest date of spore exudation was May 11 and the latest July 15. Very effective control under epidemic conditions has been obtained by applications of Bordeaux mixture made 3, 5, and 7 weeks after petal fall. All three sprays are essential for adequate control. Their relative importance varies according to seasonal conditions.

Cedar Rust.—Three years of study at Mt. Jackson has demonstrated that the intensity of infection of apple trees is proportionate to the distance between the apple trees and red cedars. If the infection obtained at one mile is rated

100 per cent., that at one and one-half miles becomes 70 per cent., that at two miles 32 per cent., and that at two and one-half miles 4 per cent. The two-mile cedar-free zone under these conditions is necessary for adequate protection of apple trees.

Scald Prevention.—Shredded oiled paper and oiled paper wraps have given excellent prevention of scald in cold storage during three years of study. Oil emulsion applied as a spray to the fruit at harvest time and shortly before gave no protection. German peat was proved ineffective. The coating of apples with paraffin has been under investigation for one season and the results are as yet inconclusive.

Spray Materials.—The dry-mix sulfur-lime has been studied extensively and has proved an excellent spray material for peaches and apples. It gives adequate control of peach scab and brown rot and of apple scab. It was not, however, effective for cloud of apples. When used as a summer spray on the fruit of York Imperials it produces a finish that is superior to that obtained with Bordeaux mixture. Spray injury may result when the material is applied on apples during very hot weather.

The use of calcium sulfide as a spray material for apple and peach has been investigated during three seasons with promising results. The material is effective as a fungicide for those diseases which are subject to control with sulfur sprays and it appears to be non-toxic when applied under conditions that usually facilitate spray injury.

Relation of air temperature to spray injury has been investigated on a limited scale with the result that lime-sulfur produced no injury at 51° F. and caused severe injury at 94°. Bordeaux mixture caused only slight injury at the high temperature and caused severe injury at the low temperature.

It has been stated that fruit drop is caused by the application of sulfur sprays at the petal fall stage. Our studies of both sprays and dusts applied at this stage on Winesap and Stayman do not confirm this theory.

The cankers which occur at the nodes of peach twigs and which have been especially abundant during recent years have been demonstrated to be caused by liberation of arsenic from arsenate of lead applied as a spray. The injury may be prevented when a slight excess of lime is added to the spray material. In experimental trials a ratio of one part of arsenate of lead to 4 parts of lime produced 35 per cent. of cankers, while with a ratio of 1:8 the production of cankers was reduced to less than 1 per cent.

Peach Scab.—A study of the production and liberation of spores of the peach scab fungus from the cankered twigs was made during the seasons of 1925 and 1926. It was found that the spores were liberated with each rain from the time of the initial production and ripening in May until the exhaustion of the fruiting bodies in the fall. In 1925 there were 13 distinct periods, beginning May 24 and ending August 21; and in 1926 there were 29 periods from

May 27 to October 5. It is evident from this that infection of fruits and twigs may result during any period of rainfall from the latter part of May until the end of the growing season. This, no doubt, accounts for the very general infection of peach twigs in commercial orchards. The disease is readily controlled by spraying, but spray applications are discontinued as a rule about one month before the fruit is expected to ripen, and the new growth is unprotected for the remainder of the season.

WALNUT TOXICITY.—The discovery that the black walnut may cause the death of apple trees growing within the area invaded by its roots was made at Winchester and later investigations proved this to be a rather common occurrence in that section. In all 49 cases of apple tree death have been studied which were clearly traceable to the presence of 19 black walnut trees. It had been suggested in a previous work by Professor A. B. Massey that the toxic factor in the walnut roots might be the organic chemical substance known as Juglone. This material has now been isolated in the pure state and preliminary tests of it indicate it to be quite toxic and it seems probable that Professor Massey's assumption will prove to be correct.

HONEYSUCKLE ERADICATION.—Studies of methods of eradication of the Japanese honeysuckle which is an important weed in apple orchards were undertaken at Crozet. It was found that the foliage and vines are readily destroyed when sprayed with waste lubricating oil. The oil may be used undiluted or in a 25 per cent. emulsion. The cheaper grades of unused lubricating oils may also be employed. Effective control is obtained if the spray is applied thoroughly in May and is rèpeated in July to destroy such new growth as may have arisen from the roots. In some cases it is necessary to apply an additional spray in May of the following year. The experiments are described in Bulletin 224.

PROGRESS AND RESULTS OF INVESTIGATIONS IN THE DEPARTMENT OF ENTOMOLOGY

By W. J. Schoene

Woolly Aphis *(Eriosoma lanigerum)*.—This problem outlined during the years 1915 and 1916 provided three distinct lines of study: (1) a search for apple root stocks resistant to aphis; (2) a test of insecticides on roots of infested apple stocks; (3) an investigation of the biology of the pest. Several years were required to develop any trees on their own roots. On one occasion some such trees were planted near Richmond, where they were subject to heavy infestation, without definite results. During the intervening years a method has been developed of propagating trees on their own roots, so that if any of the apples which are grown in this country are resistant to this insect, this will be ascertained.

As opportunity has presented itself, various insecticides which appeared to give promise have been tested, particularly calcium cyanamid, potassium cyanide, creosote emulsion, and soluble creosote. The results of these tests were reported in Volume 4, No. 1, of the Crop Pest Quarterly, issued in 1922. Thus far no insecticide has been tried which gives reasonable promise of success. This phase of the work is still being prosecuted.

The investigation of the biology was begun during 1918, by Mr. R. R. Reppert, who studied the insect at Blacksburg. For the past four years Mr. G. W. Underhill, working at Richmond, has continued the study. As a result, four papers have been published: three in 1922, and one in 1925. It is now known that the woolly aphis lives over the winter on the roots of apple trees and also in the egg stage on the American elm. The insects migrate each spring from the American elm to young apple trees. It is believed that the elm is the only source of infestation of clean nursery stock. An effort has been made to determine the exact time and duration of these migrations from elm to apple. It appears that there are some localities in the state in which the elm tree is absent, whereas, there are other localities where the tree is heavily planted. Some studies are being made to determine the infestation of apple trees in these several localities.

The Red-Banded Leaf-Roller, *Argyrotaenia* (Eulia) *velutinana*.—During the summer of 1922, the discovery was made in connection with the codling moth study that the apples in certain orchards were being injured by leaf-rollers. The leaf-rollers are feared by fruit growers and entomologists alike because the larvae are able to feed more or less on sprayed foliage. The life history of the insect was studied during the seasons of 1924 to 1927, inclusive.

During the season of 1926 and 1927, the control of the insect was investigated by the application of various sprays to apple trees in the orchard and also by spraying parts of trees in the laboratory. It has been found that by thoroughly coating both the upper and lower surfaces of the apple foliage with arsenate of lead that the leaf-roller injury can be prevented. This study resulted in the publication of Bulletin 259, entitled "A Study of the Biology and Control of the Red-Banded Leaf-Roller."

Breeding Resistant Spinach.—This was a co-operative project arranged by the Crop Pest Commission and the Virginia Truck Experiment Station in which an entomologist employed by the Crop Pest Commission worked at the Experiment Station in co-operation with the Truck Station plant pathologist. Spinach is second in importance as a truck crop in the Norfolk region. It is grown during the winter and utilizes land that would otherwise be idle. For the years 1914 to 1918, the crop had a money value somewhat in excess of one million dollars. The most serious handicap to the production of the crop was due to a disease which caused a peculiar dwarfing and discoloration of the plants called spinach blight. After a series of investigations it was proved that although the disease itself was little understood that aphis and other insects were responsible for its transmission. The results of this investigation were presented in a paper entitled "The True Nature of Spinach Blight, and the Relation of Insects to Its Transmission" in the Journal of Agricultural Research, Volume XIV, No. 1, July 1, 1918. Following the discovery that this peculiar dwarfing of the plant was due to disease and that this disease was spread from plant to plant by insects, efforts were made to produce a resistant variety of spinach. Considerable advance was made in this direction during the season of 1919 and 1920. Varieties or strains of spinach resistant to disease were developed in sufficient quantity so that seed could be supplied to seed dealers for propagation. The co-operative work continued until the Crop Pest Commission Entomologist resigned in 1920.

The Larger Corn Stalk-Borer (*Diatraea zeacolella*).—In 1918, representatives of the United States Bureau of Entomology arranged for a co-operative study of the control of the larger corn stalk-borer. Limited observations by Mr. W. J. Phillips indicated that plowing out the stubble in the autumn destroyed the overwintering worms of this insect. The purpose of this study was to carry on plowing tests in a number of localities to determine the infestation at the beginning of the winter and the percentage of worms which lived over in the corn fields both plowed and unplowed. It was found that plowing out the stubble destroyed the hibernating larva. This study resulted in the publication in June, 1921, of Technical Bulletin 22, of the Virginia Experiment Station, entitled "The Larger Corn Stalk-borer in Virginia."

Spreader Tests on Apples and Peaches.—During the summer of 1922, a series of orchard tests was made using casein and flour-paste spreaders to determine if casein increased the effectiveness of the poison spray. In these

tests neither spreader increased the effectiveness of the spray solution in protecting the fruit and foliage from these diseases. This test was reported in the Proceedings of the Twenty-seventh Annual Meeting of the Virginia State Horticultural Society (1922, pages 55 to 59).

Dusting and Spraying Truck Crops.—This work was the result of a co-operative arrangement between the Crop Pest Commission and Virginia Truck Experiment Station, in which the Crop Pest Commission entomologist assisted in the investigation of the truck crop problems. The application of insecticides to truck crops is an important subject with truckers. New pests are continuously arising, and new methods of application, and new materials are being offered to growers. In the work reported in 1920 were experiments on the spraying of tomatoes, potatoes, cucumbers, cantaloupes, egg-plants, spinach, kale, and cabbage. This project included a study of the insecticides and fungicides, methods of application, mechanism of spray, number and time of applications necessary for effective control. The work reported in 1920 and 1921 consisted in a study of the effect of application of insecticides in the form of dusts. The object was to determine the effectiveness of these various insecticides, when applied dry as compared to liquid sprays.

These studies resulted in the publication of Bulletins 30, 33, 34, 35, and 36, by the Truck Experiment Station. It appears that the dust method is applicable to the control of many truck crops, particularly the Colorado potato beetle and the aphids which attack spinach, for the control of aphids (*Myzus persicae* and *Macrosiphum solanifolii*) on spinach.

Catalpa Mealy Bug, *Pseudococcus comstocki*.—During the summers of 1923 and 1924, a study was made of the biology and control of the mealy bug that attacks the umbrella catalpa. This insect frequently occurs in large numbers on this tree. The results of this investigation were published in February, 1925, in Technical Bulletin 29 of the Virginia Experiment Station, entitled "Biology and Control of Comstock's Mealy Bug on the Umbrella Catalpa."

The Melon Beetle (*Epilachna borealis*).—The melon beetle was studied at Chester in 1920, and at Smithfield during 1921. This work was undertaken at the request of melon growers in the vicinity of Smithfield. While the melon beetle is a chewing insect, the manner of feeding together with their resistance to the poison, and the vine-like growth of the melons makes their control difficult. As a result of this study it was found that timely applications of poison to the underside of the foliage would destroy both the adults and the larvae. The results were published in July, 1923, in our Bulletin 232, entitled "The Squash Lady-Bird Beetle."

Codling Moth (*Carpocapsa pomonella*).—For many years the codling moth has been the most important insect attacking commercial apples in this latitude. During the years 1915 and 1920, fruit growers reported serious losses, a large percentage of the apples finding their way to the cull pile in spite of the application of poisons. As the biology of the pest had not been

studied carefully in this State this phase of the problem was first attacked. The work was undertaken in 1921 in a small way and enlarged later. Prior to this investigation a recommendation for orchard treatment was based largely on the observations and banding work of J. E. Buck. It was found, however, that the sprays were not applied at a time to give best results. It also developed that many growers were not making the poison application with sufficient care nor was enough material being applied to coat all parts of the foliage. In the course of this investigation it was possible to study the life history of this insect at Winchester from 1922 to 1927; at Leesburg from 1921 to 1925, and at Blacksburg during the summers of 1924, 1926, and 1927, inclusive. These studies have shown that the development of the codling moth is influenced by the weather to such a degree that variations in the weather which occur from year to year have a positive influence upon the duration of the different broods and also the number of broods. From the grower's standpoint, the most important facts are that the insects do not all emerge at one time or within a week, but that the moths continue to emerge over a long period, usually from four to six weeks; this means that to secure successful control the apple grower must keep the foliage of the trees coated with poison during the entire period in which the worms are entering fruit, or usually 35 to 40 days.

In this investigation it has been found that many worms feed to some extent on the underside of the foliage before entering the fruit. The experiments at Winchester with high pressure outfits have shown that if the trees are sprayed thoroughly it is possible to coat both sides of the foliage with the poison and to reduce the injury by the codling moth to less than 1 per cent. The first publication on these results was presented in Bulletin 248; the second publication, Bulletin 261, presents a summary of the life history study, and is now in the hands of the printer.

THE PALE-STRIPED AND BANDED FLEA-BEETLES, *Systena banda* and *Systena taeniata*.—As opportunity offered, a study was made of the life history and habits of two flea-beetles which have caused enormous losses in recent years in eastern United States. The flea-beetles become active in spring just as the young seedlings of many vegetables are coming through the ground, they attack the plant during its most critical period, and often before the farmer or trucker is aware of their presence the prospective crop is seriously injured or entirely destroyed. For many years there was some confusion as to the identity of these two insects. It was thought that the pale-striped and the banded beetles were color variations of the same species. As a result of this investigation, however, it is definitely known that the insects are not only different but that they have a different life cycle. This study has been brought together in the form of a bulletin and presented for publication during February, 1928.

Leafhoppers of Virginia.—In connection with other work and as an incidental study, L. A. Stearns, during the period of 1921 to 1925, made collections of leafhoppers. The purpose of this was to determine the species of leafhoppers occurring on our principal crops to know the damage caused. In addition, Stearns also made special studies of the life history and habits of some species of hoppers which were causing very serious injury to apple foliage. These studies have resulted in the publication of Technical Bulletin 31, entitled, "The Cicadellidae (*Homoptera*) of Virginia," which gives a list of all of the species thus far recorded in this State, and Technical Bulletin 33, which gives the life history of one leafhopper, entitled "*Erythroneura hartii* (Gill.), an Occasional Leafhopper Pest on the Apple."

The Leafhopper Project.—During recent years the apple foliage in certain sections of the State has suffered severely due to the feeding of leafhoppers; also in some orchards the fruit has been stained as a result of the presence of a large number of these insects. The work in progress consists of a study of the individual species of hoppers present in Virginia orchards to determine the conditions which seem to favor their development. It is believed that some leafhoppers migrate from other crops to the apple.

Oriental Peach Moth (*Laspeyresia molesta*).—This project has been in operation since 1918. The insect promises to be a limiting factor in peach production in this latitude. It attacks both the fruit and the twigs of the peach and sweet cherry. The insect was first noticed in 1918, in Northern Virginia, near Washington, D. C. During the years in which this investigation has been in progress the insect has spread to the peach growing localities of the eastern and central United States. The first tests indicated that the regular sprays which fruit growers applied to peaches would not prevent injury by this insect. Studies over a ten-year period have shown this to be true, and up to this time no satisfactory control measure has been found.

During this period the biology of the insect has been carefully investigated. It has been found that there are four broods each year in this State, the first of which feeds upon the twigs and the others upon the fruit. During this period experiments have been conducted with all of the well known insecticides; of these, it appears that nicotine or some similar insecticide which destroys the insect in the egg stage gives the greatest promise. It has been found that a large percentage of the larvae pass the winter in the soil and these may be destroyed by thorough cultivation. The search for an ovicide to destroy the insect in the egg stage is still being continued. The parasites have been studied to some extent and this work is now being amplified. It has been found that in some years and in some orchards that the larvae are greatly reduced by parasites. This is a very fruitful field for further study. The recommendations at present to growers include the production of mid-season varieties, careful cultivation of the orchard, and complete destruction of all wormy fruit, together with the regular peach sprays.

These studies resulted in the publication of Technical Bulletin 21, entitled "The Life History of the Oriental Fruit Moth in Northern Virginia," and Bulletin 234, entitled "The Present Status of the Oriental Fruit Moth in Northern Virginia, with report of recent orchard spraying experiments on its control."

PROGRESS AND RESULTS OF INVESTIGATIONS IN THE HORTICULTRAL DEPARTMENT

By Fred W. Hofmann

In the following statement a sketch is made of the experimental work in the horticultural department for the period July 1, 1919, to June 30, 1927. Up to the present time records have been made for tree growth and yields of apple trees subjected to various cultural and fertilizer treatments. Although several more years are still necessary for clear cut and definite conclusions, such results as have been secured may be given tentative interpretation.

In order that certain requirements may be met, these data were analyzed from a statistical standpoint. It is not enough merely to strike and compare averages. Characteristic variations such as are found from season to season and otherwise must be taken into account to study the net gain or differences between treated and untreated trees. In other words, a certain calculated average or mean together with probable departures or probable errors must be computed. These means together with their departures which go both in a minus and positive direction can then be fairly compared and the net gain or difference between treated and untreated trees obtained.

Although a statistical analysis of the records for all of the various experiments of the horticultural department are under way, more attention has been devoted to data secured from the experimental orchards at Blacksburg, Crozet, and Winchester. The writer will try as far as possible to bring out this statement in such a manner so as to make clear the trend of the investigations.

Experimental Orchard at Blacksburg

The Blacksburg experimental orchard was designed to study the role of fertilizers and moisture in tree growth and fruit bud formation. This orchard, composed of Stayman Winesap, and York Imperial with Grimes as fillers, was planted in April, 1911. The Grimes were taken out in 1927. This orchard is arranged in three series of eight plats each. Series I receives clean cultivation, Series II receives three cultivations, and Series III is uncultivated and kept in sod. Each series is subdivided into eight plats of six Stayman Winesap and six York Imperial trees. Up to 1927 these trees were interplanted with Grimes. Plats 1 and 5 are check plats which receive no fertilizers. Plat 2 receives nitrate, Plat 3 phosphate, Plat 4 potash, Plat 6 nitrate and phosphate, Plat 7 nitrate and potash, and Plat 8 nitrate, phosphate, and potash. Each year the trunk circumference and the number of pounds of fruit for each tree are recorded.

Statistical study of the yield records has been made and the results are presented herewith. These studies for trunk growth are not quite complete. Allowance for probable departure due to variation is indicated by the probable error. The gain or difference is thus shown with its respective probable error. By dividing the probable error into the gain or difference a quotient is secured from which odds are computed. These odds can be determined from a standard table such as the one prepared by Pearl and Miner. Certain predictions may then be made on the basis of the odds shown. The gains or differences between variously treated and non-treated (check) plats, the probable errors, and the odds are shown in Table 9 for the Blacksburg orchard.

In all series Stayman Winesap shows better gains where a complete nitrate, phosphate, and potash fertilizer was applied. This variety shows the next highest response where nitrate alone or in combination with phosphate or potash was applied. In the complete fertilizer or nitrogen combination plats Grimes shows better gains than in the other plats. Better responses are shown by York in non-cultivated nitrate alone, nitrate in combination, and complete fertilizer plats. York as a variety is not in accord with the other varieties. Special study must be given to this variety. It is quite likely that records made through the crest of the heavier yielding ages will reveal more definite response in this variety. With the exception of Plats 3 and 4 of Stayman Winesap, no significant responses show up where phosphate or potash alone was applied.

On the whole the better responses show up in the complete fertilizer application or where nitrate is applied with phosphate or with potash. This shows that for better gains a correct balance of nitrogen, phosphorus, and potassium must be present. Just what this balance should be and in what proportions nitrate, phosphate, and potash should be applied is a very important matter.

Experimental Orchard at Crozet

Three different cultural series and eight fertilizer plats such as at Blacksburg were duplicated in the experimental orchard at Crozet, which was also planted in April, 1911, using Stayman Winesap and Winesap with York Imperial as a filler. This duplicate experiment was designed to secure data for the same problem but under other soil and environmental conditions.

An analysis of the fruit yields recorded for each tree and plat shows that Stayman Winesap produced higher gains in the plats that received an application of nitrate in combination with phosphate or potash or with both. (See Table 10.) In Series II a better response is shown in the plat that received nitrate alone. However, on the whole, the better gains show up where nitrate with either phosphate or potash or with both is applied. Winesap also shows a better gain in Series II with nitrate used alone. In the other series and as a whole, nitrate with either phosphate or potash or with both shows higher gains. Although nitrate alone shows higher gains for York than either phosphate or

potash, the higher responses are found when nitrate is applied with either phosphate or potash or with both. It will be noted that at Crozet the Stayman plats in several respects show up like the Blacksburg plats. This variety in both orchards shows up better than York for phosphate or potash. However, the higher responses are confined to nitrate with either phosphate or potash or with both.

Conclusions

From the results secured in both the Blacksburg and the Crozet orchards, an application of a fertilizer carrying nitrogen, phosphorus, and potassium is most likely the safest blanket recommendation to offer. York seems to be the most fastidious of the four varieties observed. The consistent behavior of Stayman, Grimes, and Winesap, as against some peculiar inconsistencies of York, emphasizes the necessity of giving this variety very special study. As a matter of fact, in connection with fertilizer responses, a great field is open for particular studies of varieties in themselves. These individual varietal responses to fertilizer applications must be given detailed study. It will quite likely be revealed that certain varieties and even certain individuals within a variety are more efficient or less efficient feeders and for this reason show response differences.

The exact detailed conditions of individual trees, even of an orchard or orchard locality, may not or cannot sometimes be ascertained. Under such conditions, what is the best blanket recommendation in the application for fertilizers? Results from the experimental orchards at Blacksburg and Crozet show with certainty that a complete fertilizer gives the highest yields. Nitrogen and phosphorus or nitrogen and potassium plats show better responses than nitrogen alone. Similar localities should, therefore, be benefited with the application of a fertilizer containing nitrogen, phosphorus, and potassium. Undoubtedly, nitrogen is the important element, but for the best yields it must be in a certain balance with phosphorus and potassium. The proportions which will bring about a correct balance is a special problem for special conditions. However, it would seem advisable that some blanket formula might be suggested. Such a formula could act as a guide and perhaps as a measuring point.

In order that a beginning may be made, let us consider nitrogen, phosphorus, and potassium in the proportion, respectively, of 4 to 1 to 3. Nitrogen is an important essential but phosphorus and potassium must be present in a certain proportion. To be on the safe side and yet not losing much in the additional expense involved, it should be well to add these two elements in the proportion thus suggested. If the special conditions of the soil are known, then, of course, the proportions of these fertilizers may be modified accordingly. However, in general, for Valley and Piedmont orchards, with apple trees coming into bearing, these proportions should give profitable responses. As trees

approach the age of heavier bearing, nitrogen may be increased to a higher proportion. A blanket recommendation based upon this formula may serve as a guide and measure for the application of the correct fertilizer combination that contains these three important elements.

Round Hill Orchard, Winchester, Virginia

The so-called "on" and "off" year or biennial bearing habit of the York Imperial variety is a characteristic that is not desirable to Virginia apple growers. An annual crop is much more preferred. An experiment was, therefore, carried on at the Round Hill Orchard at Winchester for the purpose of ascertaining to what extent this habit may be controlled with the application of sodium nitrate. This was started in 1922 and the yields of each tree recorded up to 1927. Although fertilizer application has been discontinued, yield records are to be continued for several more years to study certain nitrate carry-over effects.

This orchard was divided into four series. Series I received four pounds of sodium nitrate per tree, Series II seven pounds, Series IV ten pounds, and Series III, the check none. One-half of each series, including plats 1 and 2, was cultivated, the other half, plats 3 and 4, was kept in sod. Plats 1 and 3 received all of their fertilizer in March. Plats 2 and 4 received half of their fertilizer in March and the balance in June. Single applications were thus compared with split applications.

If the application of sodium nitrate was effective in so far as inducing annual bearing this should be indicated by comparing the year to year variability. One of the ways of ascertaining variability is by means of a computation known as the coefficient of variability. This figure is secured by dividing the standard deviation (standard departure) by the mean. Presumably, the variability of the nitrated plats could be compared with the check or untreated plats. If the treated plats should show lower coefficients of variability, most likely the lessened variability thus indicated could be attributed to the respective treatment. The coefficients of the different plats were, therefore, computed and compared. These are shown in Table 11. In every instance with the exception of Plat 4, Series I, the nitrated plats of each series have lower coefficients of variability than the corresponding plats of the check where no sodium nitrate was applied. On the whole the lower coefficients appear in nitrated plats. These lower coefficients of variability associated with nitrate application most likely indicate a lessened variability and a tendency towards more equal production from year to year. Thus the application of nitrate evidently helps in bringing about less year to year variation.

It should also be noticed that the larger yields accompany the split and also the 7- and 10-pound applications of sodium nitrate. When the yields of nitrated trees of each series were paired with the non-nitrated and the differ-

ences or gains calculated by "Student's" method it was found that the higher yields prevailed significantly in the nitrated plats. The following gains and odds were secured. Series I with a 4-pound application of sodium nitrate shows a gain of 574 pounds of apples per tree with odds of certainty; Series II with a 7-pound application, a gain of 734 pounds per tree with odds of certainty; and Series IV, with a 10-pound application, a gain of 841 pounds per tree with odds of certainty.

Statistical and Interpretative Studies in Progress

Analytical studies for the purpose of interpretation and shaping conclusions are in progress with data recorded for the following projects: (1) Effects of Pruning Apple Trees on Fruit Bud Formation; (2) Effects on Apples of Time of Application of Fertilizers; (3) Effects of Severity of Pruning Young Apple Trees; (4) Correlations in so far as Growth and Yields in Apples are Concerned.

In connection with correlations in so far as growth and yields in apples are concerned several definite conclusions can be made. The following correlation coefficients have been derived in the Blacksburg and Crozet orchards between circumference of trunk and yields:

Blacksburg Orchard		Crozet Orchard	
Stayman	.73	Stayman	.61
York	.71	York	.68
Winesap	.59	Winesap	.71
All varieties	.59	All varieties	.63

These coefficients show a close correlation between circumference and yields in apples. Such information is of great value; first, from an experimental standpoint in so far as selecting comparable trees in making up pairs for more homogeneous comparison to be used in applying "Student's" method; and, second, from a practical orchardist's standpoint in so far as emphasizing that the more vigorous trees will, in the end, become the heaviest producers. There are many other points in these studies which are of great importance directly for experimental work, and which will indirectly help in the solution of practical problems.

TABLE 9.
DIFFERENCES OR GAINS IN YIELDS OF FRUIT FOR FERTILIZED PLATS. BLACKSBURG ORCHARD

Variety	Series	Plat	Gain Over Check (Pounds)	Gain Divided by Probable Error*	Odds**
STAYMAN WINESAP	I. Cultivated	2 Nitrate	643±273.2	2.35	8 to 1
		3 Phosphate	579±180	3.22	Significant
		4 Potash	580±110	5.3	Certainty
		6 Nit.-Phos.	560±182	3.08	Significant
		7 Nit.-Pot.	342±138	2.5	9.89 to 1
		8 Nit.-Phos.-Pot.	674±154	4.4	Certainty
	II. Semi-cultivated	2 Nitrate	238±89	2.62	11.58 to 1
		3 Phosphate	151±160	.94	1 to 1
		4 Potash	106±112	.95	1 to 1
		6 Nit.-Phos.	172±70	2.46	9 to 1
		7 Nit.-Pot.	850±163	5.2	Certainty
		8 Nit.-Phos.-Pot.	935±64	14.6	Certainty
	III. Sod (Not cultivated)	2 Nitrate	365±189.5	2.15	6 to 1
		3 Phosphate	45±87	.52	1 to 1
		4 Potash	-287±83	.47	1 to 1
		6 Nit.-Phos.	208±91	2.27	7 to 1
		7 Nit.-Pot.	205±173	1.19	4 to 1
		8 Nit.-Phos.-Pot.	490±69	.71	1 to 1
	All series combined	2 Nitrate	586±101.9	5.7	Certainty
		3 Phosphate	474±106.6	4.4	Certainty
		4 Potash	49±103.6	.47	1 to 1
		6 Nit.-Phos.	250±92.2	2.7	13.6 to 1
		7 Nit.-Pot.	535±100.2	5.3	Certainty
		8 Nit.-Phos.-Pot.	683±79.9	8.5	Certainty

TABLE 9.—Continued

DIFFERENCES OR GAINS IN YIELDS OF FRUIT FOR FERTILIZED PLATS. BLACKSBURG ORCHARD

Variety	Series	Plat	Gain Over Check (Pounds)	Gain Divided by Probable Error*	Odds**
GRIMES	I. Culti-vated	2 Nitrate	46±104	.44	1 to 1
		3 Phosphate	5±92	.05	1 to 1
		4 Potash	–110±104	1.06	1.18 to 1
		6 Nit.-Phos.	387±118	3.3	Significant
		7 Nit.-Pot.	–8±95.5	.08	1 to 1
		8 Nit.-Phos.-Pot.	287±138.4	2.1	5.38 to 1
	II. Semi-culti-vated	2 Nitrate	167±133	1.26	1.63 to 1
		3 Phosphate	–237±112.5	.21	1 to 1
		4 Potash	5±167	.03	1 to 1
		6 Nit.-Phos.	17±87.5	.2	1 to 1
		7 Nit.-Pot.	270±127	2.13	6.26 to 1
		8 Nit.-Phos.-Pot.	326±79	4.13	Certainty
	III. Sod (Not culti-vated)	2 Nitrate			
		3 Phosphate	–56±93	.6	1 to 1
		4 Potash	–16±70.5	.2	1 to 1
		6 Nit.-Phos.	155±96.3	1.6	2.6 to 1
		7 Nit.-Pot.	618±106	5.83	Certainty
		8 Nit.-Phos.-Pot.	599±77.6	7.85	Certainty
	All series combined	2 Nitrate	163±58	2.81	16 to 1
		3 Phosphate	–37±52	.71	1 to 1
		4 Potash	–29±62	.47	1 to 1
		6 Nit.-Phos.	159±62	2.56	9 to 1
		7 Nit.-Pot.	273±68.5	4	Certainty
		8 Nit.-Phos.-Pot.	408±57	7.16	Certainty

TABLE 9.—Continued

DIFFERENCES OR GAINS IN YIELDS OF FRUIT FOR FERTILIZED PLATS. BLACKSBURG ORCHARD

Variety	Series	Plat	Gain Over Check (Pounds)	Gain Divided by Probable Error*	Odds**
YORK IMPERIAL	I. Cultivated	2 Nitrate	-469 ± 136	3.45	Significant
		3 Phosphate	-379 ± 163.6	2.3	7 to 1
		4 Potash	-404 ± 123	3.29	Significant
		6 Nit.-Phos.	-468 ± 137.2	3.41	Significant
		7 Nit.-Pot.	-83 ± 138	.6	1 to 1
		8 Nit.-Phos.-Pot.	19 ± 190	.1	1 to 1
	II. Semi-cultivated	2 Nitrate	-105 ± 115	.91	1 to 1
		3 Phosphate	-150 ± 113	1.33	1.6 to 1
		4 Potash	445 ± 265.6	1.68	2.5 to 1
		6 Nit.-Phos.	308 ± 300.5	1.03	1 to 1
		7 Nit.-Pot.	200 ± 258	.8	1 to 1
		8 Nit.-Phos.-Pot.	291 ± 257	1.13	1 to 1
	III. Sod (Not cultivated)	2 Nitrate	469 ± 132	3.55	Significant
		3 Phosphate	-137 ± 52	2.63	11.5 to 1
		4 Potash	-93 ± 91.5	1.02	1 to 1
		6 Nit.-Phos.	150 ± 77.7	1.09	1 to 1
		7 Nit.-Pot.	546 ± 134	4.08	Certainty
		8 Nit.-Phos.-Pot.	1062 ± 71.6	14.08	Certainty
	All series combined	2 Nitrate	34 ± 126.1	.27	1 to 1
		3 Phosphate	-217 ± 139.5	1.56	2 to 1
		4 Potash	-114 ± 144.3	.8	1 to 1
		6 Nit.-Phos.	-158 ± 135.7	1.16	1 to 1
		7 Nit.-Pot.	139 ± 123.2	1.1	1 to 1
		8 Nit.-Phos.-Pot.	350 ± 118.7	3	22 to 1

*Any quotient less than 1 has odds of 1 to 1. Quotients above 3.1 are mathematically significant and those above 4.1 indicate certainty as far as human events go.

**The figures indicate the odds or chances against the occurrence of a departure that is as great or greater than that shown by the probable error, if the respective treatment were to be tried again under similar conditions. From these odds predictions can be made with corresponding assurance as to the chances of encountering greater variation than the one indicated. After departures such as year to year variations in yield and the like are accounted for and the chances of their re-occurrence computed, the net gain or difference is more clearly defined. For instance in Plat 8, Series I of Stayman Winesap with odds of over 332 to 1 the chances are certain as far as human events go that the complete fertilizer treatment produced a significant gain in yield over the check or non-treated plat. Altho odds of less than 25 to 1 are not considered mathematically significant, odds as low as 4 to 1 may sometimes be considered a safe bet.

TABLE 10.
DIFFERENCES OR GAINS IN YIELDS OF FRUIT FOR FERTILIZED PLATS. CROZET APPLE ORCHARD

Variety	Series	Plats	Gain Over Check (Pounds)	Gain Divided by Probable Error*	Odds**
STAYMAN WINESAP	I. Cultivated	2 Nitrate	161±80	2.01	5 to 1
		3 Phosphate	104±83.5	1.2	1.3 to 1
		4 Potash	191±82.4	2.3	7 to 1
		6 Nit.-Phos.	291±136	2.14	5 to 1
		7 Nit.-Pot.	294±75.7	3.9	Significant
		8 Nit.-Phos.-Pot.	716±84.5	8.5	Certainty
	II. Semi-Cultivated.	2 Nitrate	397±62	6.4	Certainty
		3 Phosphate	94±25	3.76	Significant
		4 Potash	44±41	1.07	1 to 1
		6 Nit.-Phos.	272±61	4.41	Certainty
		7 Nit.-Pot.	379±141	2.69	13 to 1
		8 Nit.-Phos.-Pot.	116±58.4	2	4.6 to 1
	III. Sod (Not cultivated.)	2 Nitrate	118±60.5	2	4.6 to 1
		3 Phosphate	93±36	2.6	11 to 1
		4 Potassium	91±36	2.5	9.8 to 1
		6 Nit.-Phos.	557±59	9.44	Certainty
		7 Nit.-Pot.	342±54	6.33	Certainty
		8 Nit.-Phos.-Pot.	276±53	5.21	Certainty
	All series combined	2 Nitrate	240±43	5.6	Certainty
		3 Phosphate	4±39	.1	1 to 1
		4 Potash	65±39	1.67	1 to 1
		6 Nit-Phos.	340±48	7.1	Certainty
		7 Nit.-Pot.	279±49	5.7	Certainty
		8 Nit.-Phos.-Pot.	330±61.5	5.4	Certainty

TABLE 10.—Continued

DIFFERENCES OR GAINS IN YIELDS OF FRUIT FOR FERTILIZED PLATS. CROZET APPLE ORCHARD

Variety	Series	Plats	Gain Over Check (Pounds)	Gain Divided by Probable Error*	Odds**
WINESAP	I. Culti-vated	2 Nitrate	295 ± 33.5	8.8	Certainty
		3 Phosphate	71 ± 75.5	.94	1 to 1
		4 Potash	2 ± 68	.03	1 to 1
		6 Nit.-Phos.	572 ± 99.6	5.7	Certainty
		7 Nit.-Pot.	465 ± 60	7.75	Certainty
		8 Nit.-Phos.-Pot.	565 ± 123	4.65	Certainty
	II. Semi-culti-vated	2 Nitrate	500 ± 92	5.43	Certainty
		3 Phosphate	58 ± 42	1.14	1 to 1
		4 Potash	241 ± 41.5	5.8	Certainty
		6 Nit.-Phos.	392 ± 52	7.54	Certainty
		7 Nit.-Pot.	105 ± 34	3.09	Significant
		8 Nit.-Phos.-Pot.	399 ± 56	7.13	Certainty
	III. Sod (Not culti-vated)	2 Nitrate	280 ± 56	5	Certainty
		3 Phosphate	3 ± 10.1	.3	1 to 1
		4 Potash	-63 ± 27	2.33	7 to 1
		6 Nit.-Phos.	393 ± 44.5	8.8	Certainty
		7 Nit.-Pot.	370 ± 40.5	9.1	Certainty
		8 Nit.-Phos.-Pot.	244 ± 57.5	4	Certainty
	All series combined	2 Nitrate	252 ± 43.2	5.83	Certainty
		3 Phosphate	64 ± 27.7	2.3	7 to 1
		4 Potash	50 ± 35.2	1.4	1.9 to 1
		6 Nit.-Phos.	404 ± 45.9	8.8	Certainty
		7 Nit.-Pot.	234 ± 45	5.2	Certainty
		8 Nit.-Phos.-Pot.	384 ± 59.8	6.4	Certainty

TABLE 10.—Continued

DIFFERENCES OR GAINS IN YIELDS OF FRUIT FOR FERTILIZED PLATS. CROZET APPLE ORCHARD.

Variety	Series	Plats	Gain Over Check (Pounds)	Gain Divided by Probable Error*	Odds**
YORK IMPERIAL	I. Cultivated-	2 Nitrate	65 ± 55.5	1.2	1 to 1
		3 Phosphate	35 ± 64	.55	1 to 1
		4 Potash	-4 ± 50	.08	1 to 1
		6 Nit.-Phos.	119 ± 88.5	1.3	1 to 1
		7 Nit.-Pot.	229 ± 59	3.9	Significant
		8 Nit.-Phos.-Pot.	256 ± 31	8.26	Certainty
	II. Semi-cultivated	2 Nitrate	165 ± 55	3	22.2 to 1
		3 Phosphate	-37 ± 50	.74	1 to 1
		4 Potash	46 ± 67	.7	1 to 1
		6 Nit.-Phos.	205 ± 53	3.9	Significant
		7 Nit.-Pot.	128 ± 66	1.94	4 to 1
		8 Nit.-Phos.-Pot.	-36 ± 43	.84	1 to 1
	III. Sod (Not cultivated)	2 Nitrate	173 ± 38	4.55	Certainty
		3 Phosphate	-6 ± 20.5	.3	1 to 1
		4 Potash	85 ± 36	2.36	7 to 1
		6 Nit.-Phos.	564 ± 50	11.28	Certainty
		7 Nit.-Pot.	169 ± 37	4.6	Certainty
		8 Nit.-Phos.-Pot.	225 ± 30	7.5	Certainty
	All series combined	2 Nitrate	141 ± 32.4	4.4	Certainty
		3 Phosphate	4 ± 33.6	.12	1 to 1
		4 Potash	6 ± 33	.18	1 to 1
		6 Nit.-Phos.	275 ± 50	6.87	Certainty
		7 Nit.-Pot.	156 ± 39.5	4	Certainty
		8 Nit.-Phos.-Pot.	112 ± 32	3.5	Significant

*See footnote under Table 9.
**See footnote under Table 9.

Table 11.—Variability in Nitrated and Non-Nitrated Apple Plats. Round Hill Orchard, Winchester, Virginia.

Series and Treatment	Plat 1 Single Application and Cultivated			Plat 2 Split Application Cultivated			Plat 3 Single Application Uncultivated			Plat 4 Split Application Uncultivated		
	M and E	SD	V	M and E	SD	V	M and E	SD	V	M and E	SD	V
	Pounds			*Pounds*			*Pounds*			*Pounds*		
I. 4 pounds Sodium nitrate per Tree	267 ± 25.4	85	32	348 ± 42.5	141	40	239 ± 51.0	170	71	379 ± 88.0	293	77
II. 7 pounds Sodium nitrate per Tree	236 ± 22.0	74	31	322 ± 40.8	136	42	331 ± 32.0	107	32	427 ± 87.7	290	68
IV. 10 pounds Sodium nitrate per Tree	301 ± 20.0	68	22	370 ± 70.6	234	63	357 ± 41.8	139	39	402 ± 90.4	269	67
III. (Check) No fertilizer applied	217 ± 53.9	179	82	260 ± 70.8	235	90	162 ± 35.1	117	72	133 ± 91.7	96	72

M — Mean pounds of fruit per tree
E — Probable error
SD — Standard deviation
V — Coefficient of variability

EXPERIMENTS AND INVESTIGATIONS IN THE DAIRY HUSBANDRY DEPARTMENT

By C. W. Holdaway, W. B. Ellett, and James F. Eheart

This report is a statement of the accomplishments of the research work in dairy husbandry for the period beginning July 1, 1919, and ending June 30, 1927, the greater part of which has been done in cooperation with the chemistry department. Mention will be made also of work done jointly with the National Research Council and of other departmental work of interest to dairy farmers. The accomplishments and value of this work will be stated from the standpoint of its scientific, economic, state, and institutional bearings.

Protein and Energy Requirements for Milk Production

Four phases of this problem have been dealt with in our experiments: the effects of minimum and maximum amounts of protein on the efficiency of the feeds, on milk production, and on the health of the animals; the amounts of protein and energy necessary in producing unit quantities of milk of varying composition; the values of the protein of different forage plants, grains, and by-products in producing milk; and the amounts of protein necessary for growth of young animals.

The work on the effects of maximum and minimum protein feeding has received a great deal of attention by investigators in problems dealing with feeding practice. Technical Bulletins 12 and 20 were the first to report our results demonstrating the far-reaching and inefficient results that follow the general farm practice of feeding improperly compounded rations to dairy cows. H. P. Armsby, of the Institute of Animal Nutrition in Pennsylvania, in his supervision of the series of experiments on growth in calves, conclusively confirmed our results with cows. More recently Ellenberger, of Vermont, has completed a series of several years' work which was undertaken as a supplement to Hill's work of that station, and to parallel work done at the Virginia station.

Results of the experiments made at this station demonstrated that the general feeding practices of most dairymen resulted in a direct loss of 23 per cent. of the nutrients of the rations due to depressed digestibility. That the addition of proper feeds to balance the rations would not only pay for themselves in increased milk flow and manure, but would result in an increased efficiency of the rest of the ration amounting to 23 per cent. The feed bill of the dairy cows in Virginia is over 15 million dollars annually and it can be seen at once that this is an important practice to emphasize if our dairymen are to compete with dairymen of other states who are more familiar with feeding principles.

The effects resulting from the feeding of excessive amounts of protein were equally disastrous. Flesh formation was induced at the expense of milk production, reproduction was hindered, and such feeding finally resulted in the loss of all the animals on this particular test.

Maximum and Minimum Protein Requirements for Growth of Cattle

The experiments relating to the maximum and minimum protein requirements for growth of cattle were conducted under the auspices of the National Research Council, and directed by H. P. Armsby of the Institute of Animal Nutrition. The Virginia station was selected as one of the cooperating stations because of its work in protein investigations for milk production. The results of the work were published in Bulletin No. 12, National Research Council, Vol. 2, Part 4, pp. 257-288, June, 1921. The establishment of feeding standards for growth was accomplished and, as stated before, the results of work done here were confirmed in some other points by this series of experiments.

The Amount of Protein Necessary in Milk Production

The next phase of this work was developed concurrently with the project previously mentioned. It has led to most productive results and has opened up at this time a field of progressive research which we believe will deal with the most important limiting factors underlying the future success or failure of the dairy industry in Virginia and in the South. In explanation of this statement mention will be made later of the question of the development and management of pasture and fodder crops on the depleted as well as on the more fertile soil types found in our state. The ground work for the ultimate solution of these problems and for the broadening of our field of research was laid by the work described in our Technical Bulletin 23, which accurately determined quantity measurements for nutrients in milk production and for use in evaluating results obtained later in researches on different feeds. Scientific standards were fixed by this work which other stations have subsequently verified. The advanced methods used for obtaining these results have been referred to and commented on by other workers in Indiana, New York, Massachusetts, and Missouri. After the standards were fixed, work was begun on important Southern feed stuffs and by-products and it may justly be stated that the economic results from these researches have been most gratifying, particularly in regard to three Southern products, peanut meal, soybean meal, and dried apple pomace. The extensive demand for and use of the bulletins published by this station on these feeds indicate that they have served the purpose of supplying information that has raised these farm by-products from little known, low-priced commodities to commodities that are standard and command a price commensurate with similar feeds on the national feed markets.

Peanut Meal.—There are about 50,000 tons of this material produced annually in the South. Previous work with this material, using only group trial

methods, was indefinite and assigned a rather low place to it. The work published in our Technical Bulletin 28 was critical and showed that peanut meal protein was practically equal in value to linseed oil meal, distillers' grains, and skim milk powder proteins, and much more valuable than wheat and maize proteins. Its laxative and toning properties made it a suitable substitute for linseed oil meal, which is the highest priced concentrate on the market. Within a short time after publication of the results, the College Feed Conference Board incorporated this feed in its open formula recommendations; closed formula manufacturers followed, and within a year the peanut meal supply was exhausted long before the new crop was ready, whereas previously it had been difficult to dispose of the supply and much was wasted. The price advanced from $35.00 to $45.00 per ton. On a production of 50,000 tons this means added receipts of $500,000 yearly to the producers of peanuts in the South.

Also our work on soybean meal has helped in fixing this material in the list of available concentrate feeds of known value for feeding dairy cows.

Dried Apple Pomace.—Only a few years ago the knowledge of feeding authorities on the value of apple pomace was so inadequate that this material barely paid for the cost of drying and was a waste product of the apple cider and vinegar industry. The establishment of definite values for this feed by the Virginia station has had two important beneficial results; it has demonstrated that it is profitable to dry and market this feed from a milk production standpoint, and it has demonstrated the value of apple pomace as a succulent feed to substitute for dried beet pulp in feeding cows. The prices paid for beet pulp had increased to more than twice its value for actual milk production, due to the necessity for succulency in the dairy ration. During the past two years the demand for beet pulp has diminished with a corresponding decrease in the cost of this material to dairymen to a level which was more in keeping with its value as a feedstuff.

The widespread demand for our Bulletin 243, entitled "Dried Apple Pomace Compared with Dried Beet Pulp and with Corn Silage in Feeding Dairy Cows for Milk Production," has contributed largely in bringing about these results. The production of apple pomace in Virginia amounts to about 5,000 tons annually, which if saved for productive purposes must necessarily net for the apple growers a large sum for cull apples and low grades that would otherwise be wasted. The cost of drying and marketing should not be more than $15.00 per ton and the market quotation is about $30.00. At least $75,000 additional revenue yearly is thus brought to the growers of apples in Virginia.

Feed Grinding Experiments

All farmers know that a great deal of coarse fodder and rough hay is wasted by being refused by cows in feeding. Will it pay to grind this coarse material and will the cattle eat it if ground, are questions frequently asked

by farmers. The answer found at this station was that more milk was produced by grinding rough fodders and hays, that the increase in milk production more than paid for the grinding, that more manurial value was produced from the feed, and less labor was required in handling it, and that a profit was made from a large amount of rough forage grown on the farm which in ordinary farm practice is lost. Experiments at other stations using better grade hay and fodder gave results that were less favorable to grinding because the cows refused less of the better grade hay.

Studies of the Technique of Digestibility Trials

The object in undertaking studies of the methods used in the trials for digestibility was to experimentally demonstrate some sources of error discovered in our work on protein digestibility and also to obtain corrected results to use in interpreting some data which have come out of these trials.

Technical Bulletin 32, entitled "The Importance of Properly Balanced Rations in Trials to Determine Digestibility as Shown in Experiments with Dried Apple Pomace," is now in press and will be issued shortly. The corrected coefficients of digestibility for the constituents of dried apple pomace as published in this bulletin will give definite values to this material, thus making it a standard feed stuff of known value in this list of available feeds for cows. Further work has been completed with corn as the experimental material.

The Value of Alfalfa and Timothy Hays from the Mineral and Protein Standpoint

The dairy husbandry and chemistry departments of the Experiment Station have just begun a series of experiments in cooperation with E. B. Meigs, physiologist of the Bureau of Dairy Industry, Washington, D. C., dealing with the relative value of two widely dissimilar hays commonly used by dairymen. These experiments, and others that will be conducted jointly with the chemistry, agronomy, and dairy husbandry departments, open up the field of research which, as previously stated, we believe is to be of great importance to the future welfare of the dairy industry in Virginia and in the South and which, if carried to a successful conclusion, should solve the most fundamental problem that confronts the dairy industry in the South. This problem deals with the profitable growing of pastures and forage crops.

It is desirable to investigate the nutritive values of our hays produced under different systems of farm management, and then to develop methods by which their productiveness may be increased. The protein and mineral constituents of the two hays under investigation are the two most important nutrients to be considered. Alfalfa and timothy hays grown in Virginia, of first and second grade quality, will be investigated by the methods developed in the previous experiments. Timothy hay is deficient in calcium as well as in

protein. Lack of calcium and phosphorus in the diet of a dairy cow not only may restrict milk production, but may result in bone depletion and ill-health resulting therefrom. With heavy milking cows the life of the cow may be endangered. It is very necessary to secure data on the availability of calcium and phosphorus as it is affected by hay quality, methods of harvesting, etc., so that the material itself may be grown and harvested under conditions that will favor the most suitable protein and mineral content.

Relation of Fertilizers to Composition of Grasses

The Effects of Varying Application of Nitrogen on the Protein Content of Grasses when Sufficient Lime, Potash, and Phosphoric Acid Have Been Applied to Meet Requirements is a project now under way in the chemistry and agronomy departments. As soon as pastures are available to the dairy husbandry department a supplementary project will be begun which is as follows: Grazing Experiment with Dairy Animals to Measure the Effect of Changed Composition of Pastures Due to Applications of Varying Nitrogen Supplies and Other Fertilizers to the Grasses; also the Effects of Grazing Rotation of Pasture Fields on the Total Amount of Nutrients Available for Milk Production.

It now seems possible to produce grasses containing 24 to 30 per cent. protein in the dry matter. If such is the case and if it is possible for farmers to grow more protein on the farms the purchase of such large quantities of mixed feeds would not be necessary and farmers would be able to grow a higher percentage of their dairy feed on the farms. A tremendous saving would thus be effected over the whole country.

In Virginia alone our dairymen purchase over $3,000,000 worth of high protein commercial feedstuffs annually. If pasture and forage crops are developed which have a higher content of protein, the amount of commercial feeds that will have to be purchased will be reduced in proportion to the changes effected in the crops and pastures. All of these commercial feeds are produced outside of the State of Virginia and their cost makes the production of milk at a profit difficult except under the best market conditions. Future increase in the production of butterfat for creamery butter, cheese, and condensed milk is unquestionably dependent on cheapening the cost of production on the farms. Little growth in the dairy industry can or will take place in Virginia unless some way is found to produce cheaper butterfat. Better pasture and forage crops is the answer to the question of how to produce cheap butterfat.

Furthermore, experiments in Europe have demonstrated that treatments of pastures and systems of pasture management similar to those to be investigated here have enabled dairymen to materially increase the number of head carried per acre. Also longer grazing periods are possible due to the fact that the animals can be grazed earlier in the spring and later in the fall.

As soon as pastures can be secured for the college and experimental herds, it is planned to begin pasture rotations with fields under different treatments of fertilizer. Protein and mineral analyses will be made of the grasses and estimates obtained for the dry matter consumed. Milk production will be recorded and by means of check fields comparative results will be secured. This work will be supplemented with digestibility trials to supply data for interpreting results.

Institutional Value of the Work

Reference has been made in this review to the relation of the dairy research investigation at the Virginia Experiment Station to researches of the National Research Council, Bureau of Dairy Industry of the U. S. Department of Agriculture, and several state experiment stations.

It may be excusable to state here that the research work done at this institution has been directly responsible for even more important contacts than these. The College Feed Conference Board is an organization of college nutrition teachers and investigators which formulates dairy and other rations that may be used by any agency in the country. These are called "open formula" or "public" rations. Large farmers' cooperative organizations in New York, New England, Pennsylvania, Maryland, West Virginia, Ohio, Michigan, Missouri, Wisconsin, Minnesota, and Nebraska have during the last few years bought their own ingredients, mixed the feeds, and sold them to their members. This movement has grown so rapidly that the actual feed handled by farmers for themselves under these formulas exceeded 1,000,000 tons last year. The farmers of Virginia alone will purchase 20,000 tons this year through the Virginia Feed Service and probably 2,000 additional tons through the Producers' Exchange of Richmond. These feeds are selling at from $2.00 to $4.00 per ton less than similar commercial feeds and are giving good results.

Supervision of the formulas under which this million tons of dairy feed is manufactured is entirely through the College Feed Conference Board. Monthly changes in formulas are handled by an executive committee of three members, one from Cornell University, one from Connecticut Agricultural College, and one from the Virginia Polytechnic Institute.

This board gives advice regarding the feeding of over two million cows and stipulates formulas for the manufacture of fifty million dollars' worth of dairy feed. Through its ability to make changes in formulas and to specify standards of quality, it is of great assistance in preventing the sale of undesirable feed materials to the dairymen. The combined purchasing power of these cooperative organizations is already greater than that of any other feed selling organization in the United States or elsewhere. They finance their own feed buying, own their own mills in some cases, and through a simplified sales service have been able to materially reduce the cost of selling to the consumer.

Service is rendered by the experiment station workers to many other organizations engaging in the feed selling business in the State of Virginia. Approximately fifty different formulas were computed last year, for milling companies, based on the findings of this station, and as far as is known the feeds made according to these formulas have given complete satisfaction wherever used.

The research work of this station on the feeding of dairy cows has given this institution an opportunity to participate in this field of work.

MILK INVESTIGATIONS

By W. D. SAUNDERS

EVALUATING MILK ON THE BASIS OF ITS COMPOSITION.—In 1922 a study was begun dealing with the question of quality in milk from different breeds of dairy cows and from different animals in the same breed. Comparisons were made on the basis of the number of calories furnished per pound of milk, taking into account both the fat and the solids not fat contained in the milk. Since the nutrients or valuable constituents of the milk are found in the milk solids, both the consumer and producer are interested not only in the fat content of the milk, but also in the other milk solids. It was pointed out that the price of milk should really be based upon its fat content and upon its content of other solids. By this method the producer will receive fair compensation for the cost of producing milk of high quality and the consumer will receive full value for his money.

MAKING CHEESE FROM MILK OF HIGH ACID CONTENT.—Studies are under way with the view of developing methods for making satisfactory cheese from milk which arrives at the cheese factory having an acid content greater than 0.15 per cent. In the opinion of a great many cheese makers, it is impossible to make satisfactory cheese from milk which has developed a high acid content. On the other hand, many farmers who have only a few cows are unable to deliver the milk promptly to the cheese factory and often they do not have suitable facilities for keeping the milk sweet at the farm.

Tests were made looking toward the neutralization of the acid in the milk by the use of an alkali. This was accomplished under laboratory conditions; but care is required to avoid certain complications, and this method was not introduced in the cheese factories.

Experiments were made also on the dilution of the whey with water for the purpose of reducing the acid content below 0.15 per cent. It appears that if the whey acid is held below 0.15 per cent. the cooking can be accomplished at a lower temperature and the time for cooking the curd can be extended without any damage to the curd. By this method entirely satisfactory cheese has been made from high acid milk. This method has been introduced in all the cheese factories of the State.

INVESTIGATIONS IN THE DEPARTMENT OF ANIMAL HUSBANDRY

By C. R. Nobles

Sheep Breeding.—A trial was undertaken to find out whether the quality of early spring lambs could be improved by using purebred Southdown, Dorset, and Shropshire bucks on grade ewes. Spring lambs represent a source of considerable income to farmers in southwestern Virginia. The ewes in question were pastured on a rather restricted area and in 1919 they developed severe infestation of internal parasites, which rendered it impracticable to continue the trial.

Wintering Dairy Heifers.—The fifth season of trials on feeds for the economical feeding of dairy heifers was completed in the winter of 1920-1921. The roughages used were corn silage, corn stover silage, and clover hay; the concentrated feeds used were cottonseed meal, peanut meal, soybean meal, velvet bean meal, linseed meal, gluten meal, corn, molasses, wheat, and bran. The results of these trials were published in Bulletin 225.

Winter Fattening of Beef Steers.—Beginning in 1920 and continuing for three years, feeding trials were made to determine the value of stover silage in the fattening of beef steers, to find out whether molasses could be substituted for the corn in corn silage, and to gain information on several other feeding practices. Choice feeder steers were used for this purpose. An article by R. E. Hunt, which appears at another place in this report, sets forth the details of this experiment and the results secured from the trials.

Wintering Yearling Spayed Heifers.—In 1924, a comparison was made between dry roughage and corn silage for wintering beef heifers. The animals were divided into two lots and the winter feeding period extended from January 15 to April 25, 1924. Lot 1, consisting of 13 heifers having an average weight of 797 pounds, received an average daily ration per head of 10.17 pounds of mixed hay, 6 pounds of corn stover, and all the wheat straw the animals would consume; and it cost $16.36 per head to winter these heifers for the 100-day period. Lot 2, consisting of 14 heifers having an average weight of 787 pounds, received an average daily ration per head of 29.12 pounds of corn silage, 2.70 pounds of mixed hay, 2.06 pounds of corn stover, and all the wheat straw they would consume; and it cost $16.96 per head to winter these heifers for the 100-day period. Lot 1 gained 1.53 pounds per head and Lot 2 gained 17.14 pounds per head during this period.

Both lots were turned on pasture April 25 and continued on grass until October 17. The gains in weight made on pasture by Lot 1 amounted to 2.07

pounds per head per day; while the gains in weight made on pasture by Lot 2 amounted to 1.95 pounds per head per day. Thus it may be seen that where the animals are left on pasture for the full grazing season, there is no practical difference in gains due to the effects of the winter rations here used.

HOG PASTURES WITH SUPPLEMENTS.—In 1919 an experiment was begun of raising hogs on a succession of pasture crops with supplemental feed of corn and tankage in varying amounts. The object was to find out what portion of the concentrated feeds could be economically replaced by pasture crops. The animals under experiment were divided into lots consisting usually of 8 to 10 animals in a lot. During seven years these lots were handled as follows:

Lot 1—Pasture alone, grain finished in the fall;
Lot 2— 25% ration of corn and tankage on summer pasture;
Lot 3— 50% ration of corn and tankage on summer pasture;
Lot 4— 75% ration of corn and tankage on summer pasture;
Lot 5—100% ration of corn and tankage on summer pasture;
Lot 6— 50% ration of corn and tankage in dry lot;
Lot 7— 75% ration of corn and tankage in dry lot;
Lot 8—100% ration of corn and tankage in dry lot;
Lot 9— 50% ration of corn and tankage on winter pasture;
Lot 10— 75% ration of corn and tankage on winter pasture;
Lot 11—100% ration of corn and tankage on winter pasture;
Lot 12—100% ration of corn and tankage in dry lot.

The results of this hog feeding and management experiment showed that forage crops may be used in feeding hogs so as to save a considerable amount of grain or other concentrated feeds. The details of this experiment may be found in our Bulletin 246, which was published in 1926.

SHEEP MANAGEMENT STUDIES.—In the fall of 1923 a survey was made of methods employed in handling sheep in representative areas in southwestern Virginia. The investigator visited the farms and made records concerning breeds, methods of feeding, lamb and wool production, methods of marketing, disease prevalence, and so on. The information was secured from 100 farms in this region on which sheep are an important enterprise. A detailed account of this study was published in our Bulletin 238.

SOW MANAGEMENT STUDIES.—These studies were begun in 1924 and are still in progress. The purpose is to ascertain whether there are advantages in providing pasture range for pregnant sows in addition to the concentrated feeds they receive. The results are to be measured in the success of pig production and in the economy of handling the sows by this method. This study has not yet been brought to the stage of conclusive results.

SOFT PORK INVESTIGATIONS.—This is a cooperative project in which the Bureau of Animal Industry of the United States Department of Agriculture, several stations in the Southern States, and the Virginia Experiment Station are taking part. The object is to find out to what extent certain classes of feeds, such as soybeans, and peanuts influence the hardness of the pork; and the period of time required for feeding such hogs on corn and tankage to harden

them after they have been partly raised on feeds which seem to produce the undesirable quality of softness in the pork. This line of investigation gives promise of great practical usefulness, and hog raisers in a large area are interested in the results.

Quality and Palatability in Beef.—A large number of state experiment stations and several bureaus in the United States Department of Agriculture are cooperating in this study. The Virginia Experiment Station is working on a phase of the problem dealing with finishing beef steers on grass, some with and some without a grain supplement while on grass; and one lot of steers is grain fed in the barn for a period of time after the grazing season is over and before marketing. The third year of this experiment is now in progress. At the proper time the steers are shipped to the government slaughter plant at Beltsville, Maryland, and there the carcasses are tested for quality and palatability.

INVESTIGATIONS CONDUCTED IN THE DEPARTMENT OF ZOOLOGY AND ANIMAL PATHOLOGY

By Russell A. Runnells

The experiment station work of the department of zoology and animal pathology was begun August 1, 1924. During the year following, an attempt was made to survey the field of animal diseases in Virginia to determine, if possible, what particular diseases nedeed investigating. During that year 97 autopsies were conducted, tissue from 33 animals was examined, and the blood of 722 hens was tested for bacillary white diarrhea infection.

Sheep Diseases.—During the winter of that year sheep diseases were investigated. Sheep raisers were of the opinion that some specific infectious disease was causing severe losses among their flocks. The investigation revealed that in most cases their losses were due to a combination of conditions, namely: internal parasites, including stomach worms, nodule-producing worms, lung worms, whip worms, and tape worms; external parasites, lice and ticks; improper feeding; poor housing during inclement weather; pink eye (infectious ophthalmia); twin pregnancy at time of low vitality; old age.

Bacterial Flora of Mammary Glands of Dairy Cows.—During 1924-25 we made an investigation of the bacterial flora of the mammary glands of dairy cattle with special reference to pathogens. This problem was pursued because of the presence of mammitis or garget in the college dairy herd. Staphylococci and streptococci were found but the frequency of their appearance was diminished by making a radical change in the method of washing the cows' udders before milking. When mammitis was most prevalent this washing was done with a hose. Cold water and a rather strong water pressure apparently exerted a devitalizing influence upon the udder and paved the way for the bacterial infection.

Chicken Pox.—During the fall of 1924 an outbreak of chicken pox occurred in the college poultry flock. As a result, an immunization experiment was begun. The results in the college flock were so encouraging that a carefully controlled experiment was conducted during the next two years. In all, 107 birds were used for this work. Approximately half of them were vaccinated and the other half left as controls. The controls ran with the vaccinated birds during the experiment. The vaccinated birds contracted the disease as soon as the unvaccinated ones, and appeared to have just as severe a form of the disease as the unvaccinated ones. Therefore, we do not recommend vaccination against chicken pox in poultry as it is now being done.

Bacillary White Diarrhea.—In 1925 we began our studies on the effects of bacillary white diarrhea infection on hens, eggs, and chicks, together with

studies on the serological test used in diagnosing this disease in the adult fowl and on the effect of fowl typhoid vaccination on this test. Practically all of these studies will be completed this year. The experiments thus far show that:

1. Infected hens
   a. Quite consistently react to the blood test;
   b. Lay fewer eggs than non-infected hens;
   c. Live shorter lives than non-infected hens;
   d. Have diseased ovaries.
2. Eggs from infected hens
   a. When incubated do not hacth as many chicks as eggs from non-infected hens;
   b. Frequently contain the white diarrhea germ;
   c. Frequently transmit the disease to healthy chicks;
   d. May grow to maturity and harbor the infection.

Much work has been done to perfect the blood test for this disease. We have cooperated with several other experiment stations in this work. As a consequence of this work a standard test has been adopted. In addition to this, we have made an application of a new rapid method test to the diagnosis of this disease. Our diagnostic laboratory tested 95,000 samples with this test this year (1927-28). By the use of it the cost of testing has been reduced half. Formerly we charged 8c per sample for testing. Now the cost is 4c.

Our experimental data show that hens should not be tested for white diarrhea infection within a period of at least two months after they have been vaccinated against fowl typhoid, because the typhoid vaccination interferes with the blood test for white diarrhea infection.

OTHER INVESTIGATIONS.—A project in the control of abortion infection in cattle has been begun. It involves periodic blood testing and segregation of infected animals.

A project which has not yet been outlined but for which material has been collected during the past year deals with fowl paralysis, a new disease of young birds that resembles infantile paralysis of the human.

Another project which was carried on as a side issue this past year was a test on certain worm remedies for poultry that are being recommended at the present time. These agents were kamala for tape worms, nicotine sulphate for round worms, a combination of kamala and nicotine sulphate for both round and tape worms and iodine vermicide (Chandler) also for both round and tape worms. Over 60 birds were used for these tests. Kamala proved to be effective for tape worms, nicotine sulphate for round worms, but kamala and nicotine sulphate combined did not remove round and tape worms. Sufficient tests were not conducted on iodine vermicide to justify making a statement concerning its efficacy.

PROGRESS AND RESULTS OF INVESTIGATIONS IN THE AGRONOMY DEPARTMENT

By T. B. Hutcheson and T. K. Wolfe

A Study of the Principles Governing Growth and Maturity of Corn.—The results secured under this project since 1919 have been reported in our Technical Bulletins Numbers 26, 27, and 30. The project has recently been revised and the effects of nutrition on growth and maturity is now being studied. Some of the conclusions which may be drawn as a result of this study are:

1. On the Hagerstown soil at Blacksburg, applications of phosphate fertilizers hasten maturity of corn. However, pot experiments in the greenhouse show that if any of the commonly applied plant food elements are deficient in the soil, growth and maturity are retarded.
2. First generation corn hybrids are usually earlier maturing than the average date of maturity of their parent varieties.
3. Small kernels germinate more quickly but mature later than large kernels.
4. There is a positive correlation between size of stalk and size of ear and yield in corn.

Cereal Investigations

Corn Breeding and Selection.—The work along this line has had as its most important purpose the development of strains of corn suited to Southwest Virginia conditions. The cross, Boone County White x Silver King, continues to give much promise. About 20 acres are being grown to secure seed for distribution. The yields of the cross in comparison with its parents are shown in Table 12.

Table 12.—Yields per Acre of Grain in Bushels and Stover in Tons and the Percentage of Marketable Grain of Boone County White and Silver King Varieties of Corn and of the Cross Produced from Them. Average for Seven Years, 1920 to 1926

Variety or Cross	Grain, bus.	Marketable Grain, per cent.	Stover, tons
Boone County White	45.11	75.01	2.25
Silver King	41.50	82.53	.83
Cross	50.85	82.27	1.10

The results set forth in Table 12 show that the cross has outyielded both parents based on the seven-year average. It produced a higher percentage of marketable corn than Boone County White and just as high a percentage of

marketable grain as Silver King, which is an early-maturing variety. The yield of stover of the cross is intermediate between the parents. This variety matures sufficiently early to escape frost in the high altitudes of southwestern Virginia.

V. P. I. Prolific corn, a cross between Cockes Prolific and Virginia White Dent, continues to give good results, and there is a good demand for the seed. The results presented in Table 13 show that this cross is an outstanding one. This is an early silage variety.

TABLE 13.—YIELDS PER ACRE OF GRAIN IN BUSHELS AND STOVER IN TONS AND THE PERCENTAGE OF MARKETABLE GRAIN OF VIRGINIA WHITE DENT, COCKES PROLIFIC AND V. P. I. PROLIFIC VARIETIES OF CORN. AVERAGE FOR FOUR YEARS, 1922, 1924, 1925 and 1926

Variety	Grain, bushels	Marketable Grain, per cent	Stover, tons
Virginia White Dent	37.11	58.81	2.30
Cockes Prolific	38.76	79.32	2.59
V. P. I. Prolific	45.29	86.87	2.26

A cross between V. P. I. Prolific and Leaming varieties of corn was self-pollinated to study the behavior in reference to the silage-type stalk. The object of this cross is to secure a silage-type corn with yellow kernels with the view of increasing the vitamin content of silage. The cross is now breeding true for yellow kernels and the work during 1926 indicated that silage-type stalk is dominant to grain-type stalk. During 1927 ears which bred true for both yellow kernels and silage-type stalks were observed and allowed to intercross. In the season of 1927 a silage-type corn with yellow kernels was secured. The yielding ability of this variety in comparison with other silage varieties will have to be determined, which will require several years.

The corn breeding work by the Jones method is being continued. In 1926 some double crosses of Silver King corn were made. These crosses are being tested for yield. The improvement of Reid's Yellow Dent corn by the Jones method was started in 1926.

The one year's results reported in Technical Bulletin 26 show that seed corn selected from large stalks does not yield any higher than that selected from small stalks. The results so far secured show that although large stalks produced more grain than small stalks, the yielding capacity of the seed of the large stalks is no greater than that of the small stalks.

WHEAT BREEDING AND SELECTION.—The selections V. P. I. No. 131 and V. P. I. No. 112 made in 1909 have been tested out thoroughly and have shown their superiority as shown in Table 14.

TABLE 14.—YIELDS PER ACRE IN BUSHELS OF WHEAT VARIETIES AND SELECTIONS (11-YEAR AVERAGE, 1915–1917 and 1919–1926)

Variety or Selection	Grain (bushels)
Fulcaster (bearded)	19.49
Fultz (smooth)	19.10
V. P. I. No. 112	22.52
V. P. I. No. 130	22.39
V. P. I. No. 131	21.61
V. P. I. No. 136	20.28

The selections shown in Table 14 were made from Fulcaster except V. P. I. No. 112, which is a selection from Poole. The results show that V. P. I. No. 112 and V. P. I. No. 131 are as good as any of the selections and yield higher than the two leading commercial varieties of the State, Fulcaster, and Fultz. The variety tests show that spring wheat is practically worthless in Virginia and should have no place in her agriculture.

OAT BREEDING AND SELECTION.—V. P. I. No. 1, segregated in 1919, continues to give good results on the farms in the State. However, there is needed a strain of this oats with taller straw and more cold resistance than it now possesses. Work is now under way with these objects in view. The cooperative oat experiment between this department and the U. S. Department of Agriculture started in 1926 and is being continued. Several promising selections of Virginia Gray Winter oats were made in the spring of 1927 from the head selections planted in the fall of 1926. There is a great demand for a superior strain of this variety.

Fertilizing Pasture Grasses

The purpose of this experiment is to study the effects of fertilizers on pasture grasses and also to determine the best pasture grasses for this section. The indications from this experiment at present are that:

1. Bluegrass, orchard grass, and white clover is the most satisfactory combination of pasture plants for the fertile limestone soils of the State.
2. Orchard grass, redtop, sheep fescue, and white clover make a satisfactory combination of pasture plants for the less fertile soils of the State.
3. Lime and phosphate applications to pastures cause white clover to come in and greatly improve the pastures.
4. Constant clipping or grazing reduces the yields of dry matter but increases total yields of protein.
5. The protein and mineral content of pasture grasses is not measurably increased by fertilizers used at small rates (16

to 20 pounds of nitrogen, 40 to 50 pounds of phosphoric acid, and 40 to 50 pounds of potash to the acre). This experiment has been revised recently and rather extensive work is now being carried on to determine the effect of heavy applications of nitrogen on yields and protein content of pasture grasses.

Forage Investigations

These investigations include the work that is being done with soybeans, red clover, sweet clover, and lespedeza.

SOYBEANS.—With the exception of the cultivation test with soybeans, the cultural tests were discontinued in 1925. The cultivation test was discontinued at the close of the growing season of 1926. The results for the five years of the test are given in Table 15.

TABLE 15.—THE EFFECT OF HARROWING AND CULTIVATING SOYBEANS ON YIELD OF HAY

Method of Seeding and Cultural Treatment	Average Yield of Hay in Tons per Acre from 1922 to 1926, inclusive
Broadcast—no cultivation	2.01
Broadcast—harrowed when plants were breaking through the ground	2.97
Broadcast—harrowed when plants were three inches tall	2.50
In rows—no cultivation	2.01
In rows—one cultivation	2.83
In rows—two cultivations	2.98
In rows—three cultivations	3.40
In rows—harrowed when plants were breaking through ground and two cultivations later	2.62
In rows—harrowed when plants were three inches tall and two cultivations later	3.13

The selection work with the Virginia and Ito San varieties is being continued. The study of the effects of fertilizers on the germination of soybeans shows that fertilizers, acid phosphate, and 8-3-3 reduce the germination and yield of soybeans when applied with the beans when the soil is dry at the time of planting. However, if the soil contains an abundance of moisture at the time of seeding, the germination of the beans is not decreased and the yields are increased when the fertilizers are applied when the beans are seeded as compared with the results secured when no fertilizer is applied. Since it is not known at the time of seeding beans whether the season will be wet or dry, it is advisable to apply the fertilizer and then seed the beans.

RED CLOVER.—The results secured with red clover from 1922 to 1926, inclusive, were reported in Bulletin 252. These results show that European

clover seed usually produce poor crops in this State and that the best clover seed for the section are those obtained from nearby regions in the anthracnose area. The results reported in Bulletin 252 show that an important cause of red clover failure in Virginia is the presence of anthracnose. Red clover seed from some sources are more resistant to anthracnose than that from others. Experiments are now under way with the view of selecting anthracnose-resistant strains of Virginia-grown red clover. It seems that crops of red clover produced from seed that has been grown in Virginia for a number of years are resistant to the anthracnose disease. Red clover seed has been secured from a number of farmers in Virginia and attempts will be made to secure disease-resistant plants from these sources. The feasibility of growing red clover for seed in the dark tobacco section is being studied on the farm of J. R. Horsley in Appomattox County. Virginia-grown red clover seed was seeded there in the spring of 1927 and the production of seed in 1928 will be studied.

Sweet Clover.—Sweet clover is already an important crop in Virginia especially for soil improvement and for pasturage. In Table 16 is shown the yields of the different varieties of sweet clover. The White biennial leads in yields while the Hubam is by far the lowest yielding.

Table 16.—The Yields in Tons per Acre of Different Varieties of Sweet Clover

Variety	Fall 1924	Spring 1925	Fall 1925	Fall 1926	Spring 1927	Average (4 yrs.)
White biennial	3.03	1.86	.12	.62	1.12	1.69
Yellow biennial	2.30	1.52	....	.62	1.12	1.39
Hubam	1.57	....	....	.65	....	.56

In Table 17 is shown the results secured from the rate of seeding tests with sweet clover. The results indicate that ten pounds of seed per acre is just as good, as measured by yields of hay, as a higher rate of seeding.

Table 17.—The Yields in Tons per Acre of White Biennial Sweet Clover Seeded at Various Rates

Rate of Seeding in Pounds per Acre	Fall 1924	Spring 1925	Fall 1925	Fall 1926	Spring 1927	Average (4 yrs.)
10	3.03	1.10	.13	.72	1.15	1.53
15	2.75	1.45	.19	.79	.97	1.54
20	2.90	1.05	.12	.86	.93	1.47
25	2.72	1.28	.14	.75	.99	1.47

The results given in Table 18 show the effect of height of cutting sweet clover at different stages of growth on the yield.

TABLE 18—THE YIELDS IN TONS PER ACRE OF WHITE BIENNIAL SWEET CLOVER CUT AT VARYING HEIGHTS AT DIFFERENT STAGES OF DEVELOPMENT

Heights of Cutting, ins.	Stage of Development	Fall 1924	Spring 1925	Fall 1925	Fall 1926	Spring 1927	Average (4 yrs.)
2	Early bud	2.71	1.91	.15	.53	.80	1.53
2	Late bud	2.10	1.70	.07	.66	1.32	1.46
4	Early bud	1.95	1.72	.20	.70	.75	1.33
4	Late bud	2.90	1.67	.30	.97	1.68	1.88
6	Early bud	2.34	1.61	1.17	.92	.76	1.70
6	Late bud	1.80	2.83	.10	1.42	1.49	1.91

In the dates of seeding experiment with scarified and unhulled white biennial sweet clover, some very striking results were secured. They are presented in Table 19 and show that unhulled seed give much larger yields of hay than scarified seed. The highest yield of hay was secured from the February 15 seeding. This experiment was started again in the summer of 1926 and in addition to scarified and unhulled seed, hulled but unscarified seed was used. It was difficult to secure seed with the hull removed which was not also scarified. Finally some hulled but unscarified seed was secured from L. W. Kephart of the U. S. Department of Agriculture. Some of the results of the dates of seeding experiment are reported in an article entitled the Comparative Value of Scarified and of Unhulled Seed of Biennial White Sweet Clover for Hay Production. Jour. Amer. Soc. Agron. 18:1127-1129; 1926.

In Table 20 the results showing the effect of fertilizers and lime on the yields of sweet clover hay are presented. The results are inconclusive and the experiment is being continued.

LESPEDEZA.—Lespedeza seed has been collected from the top of Price Mountain and from the Shenandoah Valley at an elevation of 1,000 feet and is now being grown in comparison with common, Kobe, and Korean lespedezas at Blacksburg. It is hoped that the seed collected from Price Mountain and the Shenandoah Valley will prove valuable at Blacksburg. The common lespedeza will not mature seed readily at the altitude at Blacksburg while the Korean type will.

Rotation Experiments With Fertilizer

The results of this experiment are reported in Bulletin 253. Acid phosphate has proved to be the most profitable commercial fertilizer. Dried blood

alone has given poor results. This experiment is being conducted on Hagerstown silt loam soil. On other soils the results may be different.

TABLE 19. — THE YIELDS OF HAY IN POUNDS PER ACRE OF WHITE BIENNIAL SWEET CLOVER, SCARIFIED AND UNHULLED, AS INFLUENCED BY THE TIME OF SEEDING

Date of Seeding	Scarified Seed				Unhulled Seed			
	Spring 1926	Fall 1926	Spring 1927	Total	Spring 1926	Fall 1926	Spring 1927	Total
Aug. 1, 1925	145	0	....	145	685	800	....	1485
Aug. 15, 1925	195	0	....	195	890	125	....	1015
Sept. 1, 1925	85	0	....	85	290	645	....	935
Oct. 15, 1925	....	0	214	214	....	795	1593	2388
Nov. 15, 1925	....	0	831	831	....	1170	1804	2974
Dec. 15, 1925	....	140	742	882	....	1400	2260	3660
Jan. 15, 1926	....	95	935	1030	....	1045	2100	3145
Feb. 15, 1926	....	810	1275	2085	....	1985	2885	4870
Mar. 1, 1926	....	785	785	1570	....	1835	1200	3035
Mar. 15, 1926	....	365	665	1030	....	1595	1135	2730
Apr. 1, 1926	....	335	744	1079	....	1450	1650	3100
Apr. 15, 1926	....	0	147	147	....	0	400	400

TABLE 20.—THE INFLUENCE OF FERTILIZERS AND LIME ON THE YIELD IN TONS PER ACRE OF SWEET CLOVER HAY

Treatment per Acre	1923	1924	1925	1927 (Spring cutting)	Average
Check	2.60	1.59	1.07	1.24	1.63
Acid phosphate, 300 lbs.	2.79	1.96	1.62	1.36	1.93
Nitrate of soda, 100 lbs. Acid phosphate, 300 lbs. Muriate of potash, 100 lbs.	2.66	2.11	1.29	1.18	1.81
Acid phosphate, 300 lbs. Muriate of potash, 100 lbs.	2.14	1.21	.93	.84	1.28
Limestone, 2 tons	3.13	1.64	1.74	.78	1.82
Limestone, 2 tons Acid phosphate, 300 lbs.	3.15	1.87	1.51	1.07	1.90
Check	2.90	2.09	1.42	.28	1.67

Phosphate and Sulphur Experiment

The purpose of this experiment is to compare different sources of phosphoric acid and ammonia in a rotation of corn, wheat, and hay. Where other phosphate carriers are compared with superphosphates, gypsum is added to them in the same amount as that found in the superphosphate treatment. This experiment is being continued and some of the results were reported in Bulletin 253.

One of the phases of the experiment was to determine the value of the phosphorus in different phosphate carriers when all the carriers contained gypsum. In case of corn, basic slag, floats, and bone meal gave about the same amount of corn, while superphosphate gave somewhat less. Superphosphate gave the highest yields of wheat and hay. In case of wheat, basic slag ranked next to superphosphate, followed in order by floats and bone meal. Basic slag, floats, and bone meal gave about the same yield of hay.

A comparison was made of the value of different sources of ammonia in combination with floats, muriate of potash, and gypsum equivalent to that in the superphosphate. The amount of ammonia supplied was equivalent to that in six tons of manure. In case of corn, there was but little difference in yield as effected by different sources of ammonia. However, dried blood leads. In case of wheat, manure leads, followed by dried blood. Nitrate of soda gave the highest yield of hay, followed by manure. The ammonia carriers used were nitrate of soda, ammonium sulphate, dried blood, and manure.

When the comparison of the ammonia carriers was made in combination with superphosphate and muriate of potash, manure gave the highest yield of corn and hay but ammonium sulphate gave the highest yield of wheat. There was but little difference between the effects of the other carriers. Manure plus superphosphate has given higher yields of corn, wheat, and hay than manure and floats, manure and basic slag, or manure alone. Superphosphate applied in sufficient quantities to furnish 60 pounds of phosphoric acid has given on the whole as good or better results than floats. Floats to which sulphur was added gave higher yields of wheat and hay but a lower yield of corn than floats and gypsum or superphosphate. Superphosphate applied once in six years at a rate of 360 pounds of phosphoric acid during the period gave better results than an equal amount of phosphoric acid from floats.

Gypsum in combination with dried blood and muriate of potash has given slightly lower yields than dried blood and muriate of potash without gypsum. On the whole, the yields of corn and hay of the control plats have been as high as those of the treated plats. However, the treated plats, as a rule, have given higher yields of wheat. In time this experiment should give some much needed information as to the value of different sources of phosphorus, ammonia, the rate of application of floats and superphosphate, and the value of gypsum as a fertilizer.

Lime Experiments

The more important results of these experiments have been reported in our Bulletin 253. It has been found that there is no difference in results obtained from burnt lime, ground limestone, and precipitated marls provided the same amount of calcium oxide is applied to the acre in each case. In rotations of corn, wheat, clover, and grass the use of lime has been found quite profitable. It is thought, however, that the chief benefit of the lime is to the clover in the rotation and that the increase in the other crops is largely due to the larger crops of clover produced where lime was used.

Legume Experiment

In this experiment crimson clover and vetch, used as a cover crop in corn, is compared with rye used for the same purpose and with no cover crop.

Even where crimson clover and vetch were removed for hay, soil productivity has been maintained and erosion controlled. Rye has proved markedly inferior to crimson clover and vetch as a cover and green manure crop and it seems likely that its chief value as a cover crop is in reducing erosion. Soils without cover crops have eroded badly and at the end of an eight-year period are badly gullied and the crop yields have been reduced to practically nothing.

Alfalfa Experiments

These experiments show that July 15 to August 15 is the best time for seeding alfalfa in this locality. They also show that for best results alfalfa must be seeded without a cover crop. Twenty pounds of high germinating seed to the acre has proved the most profitable rate of seeding. Cultivation with a spring toothed harrow or alfalfa cultivator early each spring was effective in keeping bluegrass and other weeds out of the crop and has increased yields. Top dressings of superphosphates and manure lengthened the duration of the stand and also increased yields.

Potato Studies

As a result of tuber-unit selection an outstanding strain of Bliss Triumph potato has been developed. It is very resistant to disease, the vines remain green for a long period of time, and it consistently yields high. This new strain has been named Tech Triumph. The yields of the various selections in comparison with the original variety are shown in Table 21.

Three tuber-unit selections of the V. P. I. Green Mountain have proved to be superior to the parental strain as shown in Table 22.

The selections of both the Bliss Triumph and the V. P. I. Green Mountain will be tested for five years and if they continue to show up well at the end of that time they will be distributed to farmers. Increase plats of the selections

were started in 1927 in order to have a supply of seed on hand when the five-year test is completed.

TABLE 21.—YIELDS OF THE BLISS TRIUMPH VARIETY OF POTATOES AND SELECTIONS FROM IT IN BUSHELS PER ACRE OF MARKETABLE POTATOES

Selection Number and Variety	1924	1925	1926	Average
Bliss Triumph	14.07	11.20	51.04	25.44
36	112.50	6.25	60.42	59.72
197	62.50	7.29	31.25	33.68
260	72.92	3.91	22.92	33.25
278 (Tech Triumph)	197.92	27.08	89.58	104.86
Bliss Triumph	14.07	7.29	50.00	23.79
280	70.83	2.60	46.88	40.10
317	85.42	5.21	78.13	56.25
343	64.58	3.91	73.96	47.48
361	79.17	5.21	47.92	44.10
Bliss Triumph	14.07	7.29	71.88	31.08

TABLE 22.—YIELDS OF THE V. P. I. GREEN MOUNTAIN STRAIN OF POTATOES AND SELECTIONS FROM IT IN BUSHELS PER ACRE OF MARKETABLE POTATOES

Selection Number and Variety	1923	1924	1925	1926	Average
V. P. I. Green Mountain	100.69	95.49	19.80	125.00	85.25
106	140.63	116.67	23.18	145.83	106.58
115	139.58	146.88	22.40	112.50	105.34
308	176.00	114.58	16.67	145.83	113.27
V. P. I. Green Mountain	100.69	95.49	19.80	104.17	80.04

SEED POTATO EXPERIMENTS.—These experiments have been conducted as outlined in cooperation with the Virginia Truck Experiment Station. The first crop was grown in Burke's Garden and Blacksburg in 1926 and the second crop planted in 1927. The first crop was grown at both Norfolk and Onley in 1927 by the Virginia Truck Experiment Station. The yield of the potatoes at Blacksburg is shown in Table 23 and at Burke's Garden in Table 24.

TABLE 23.—YIELD OF IRISH COBBLER POTATOES IN BUSHELS PER ACRE WHEN PLANTED AT DIFFERENT DATES AT BLACKSBURG IN 1926

Date of Planting	Table Stock	Seed	Culls	Total
April 1, 1926	12.34	36.16	18.38	66.88
April 15, 1926	24.25	11.12	27.19	62.56
May 1, 1926	25.20	43.72	21.88	90.80
July 1, 1926	12.28	14.24	21.62	48.14
July 15, 1926	5.68	10.10	32.50	48.28

TABLE 24.—YIELD OF IRISH COBBLER POTATOES IN BUSHELS PER ACRE WHEN PLANTED AT DIFFERENT DATES AT BURKE'S GARDEN IN 1926

Date of Planting	Table Stock	Seed	Culls	Total
April 15, 1926	13.68	103.67	15.94	133.29
May 1, 1926	13.46	104.68	18.68	136.82
May 15, 1926	11.34	123.48	34.37	169.19
July 1, 1926	....	....	38.98	38.98
July 15, 1926	....	....	17.72	17.72

The culls included all potatoes weighing less than three ounces. The seed included all potatoes weighing from three to ten ounces, inclusive, and were true to type. Table stock included all potatoes weighing more than ten ounces and those weighing from three to ten ounces which were not true to type. At both Blacksburg and Burke's Garden the highest yield of potatoes was secured from the third date of planting. At both places the July plantings yielded low. It is not likely that it will be feasible to plant potatoes in July in Southwest Virginia due to low yield and the competition with other farm work.

Some of the potatoes from each date of planting plat were kept in crate storage and some in bins from the time of digging until shipment was made to Norfolk in November or until the potatoes were planted in the spring at Blacksburg and Burke's Garden. In addition, one bushel of potatoes from each date of planting plat was shipped to Norfolk ten days to three weeks after digging to be held in cold storage until planting the following spring. During the ten days to three weeks period the potatoes were stored in crates. Potatoes were saved at Blacksburg from the April 1 planting and at Burke's Garden from the May 1 planting. Some were kept in bins and some in crates. The seed which was to be used for the three first plantings at Blacksburg and at Burke's Garden were held in storage at Blacksburg until planting time. The seed for the July plantings were shipped to Norfolk in November and placed in cold storage until the proper time for planting. At the time of planting, both the crate- and bin-stored potatoes were examined and the kind which had kept better were used at Burke's Garden. In all cases the crate-stored potatoes proved to be better. At Blacksburg potatoes from all kinds of storage were planted in order to study the effect of storage on yield.

The crate and bin storage were located in the potato storage cellar in the basement of the plat barn at Blacksburg. There was no way to control the temperature of storage cellar except by opening and closing the windows. However, with the exception of the fall and spring, the temperature of the cellar ranged around 40° F. With the exception of the potatoes for the April 1

planting at Blacksburg and the May 1 planting at Burke's Garden, none of the potatoes were kept in storage at Blacksburg later than November. It is planned to keep hereafter some of the potatoes from all the plantings in both crate and bin storage through the winter at Blacksburg.

The loss in weight in storage and the loss due to removal of sprouts is shown in Table 25. The July plantings were placed in storage on October 15, 1926, and the Burke's Garden potatoes were placed in storage on September 10, 1926. The potatoes from the July plantings at Burke's Garden were lost after harvest. In case of the Blacksburg potatoes produced from the April 1 planting and stored in crates, .3 per cent. rotted from August 4 to November 6 and .4 per cent. from November 6, 1926, to March 28, 1927.

TABLE 25.—THE PERCENTAGE LOSSES IN WEIGHT DURING STORAGE AND BY REMOVAL OF SPROUTS OF THE POTATOES FROM THE DIFFERENT PLANTINGS STORED BOTH IN CRATES AND IN BINS

Place of Production	Date of Planting	Kind of Storage	Percentage Loss in Weight in Storage		Percentage Loss Due to Removal of Sprouts
			From Aug. 4 1926 to Nov. 6 1926	From Nov. 6 1926 to Mar. 28 1927	
Blacksburg	Apr. 1, 1926	Crate	2.7	0.9	9.5
Blacksburg	Apr. 1, 1926	Bin	2.8	0.7	0.1
Blacksburg	Apr. 15, 1926	Crate	6.4	....	....
Blacksburg	Apr. 15, 1926	Bin	6.3	....	....
Blacksburg	May 1, 1926	Crate	6.6	....	....
Blacksburg	May 1, 1926	Bin	5.3	....	....
Blacksburg	July 1, 1926	Crate	1.6	....	....
Blacksburg	July 1, 1926	Bin	0.8	....	....
Blacksburg	July 15, 1926	Crate	1.7	....	....
Blacksburg	July 15, 1926	Bin	1.3	....	....
Burke's Garden	Apr. 15, 1926	Crate	0.8	....	....
Burke's Garden	Apr. 15, 1926	Bin	1.3	....	....
Burke's Garden	May 1, 1926	Crate	0.7	5.5	8.4
Burke's Garden	May 1, 1926	Bin	0.4	1.7	2.9
Burke's Garden	May 15, 1926	Crate	1.0	....	....
Burke's Garden	May 15, 1926	Bin	1.2	....	....

Orchard Grass Breeding and Selection

The orchard grass breeding experiment is being continued. Twelve outstanding strains have been selected from the 300 original selections made. Self-pollinated seed was secured from these twelve strains in 1927. The seed were planted during the fall of 1927 in comparison with plants taken from the parental strains. It is proposed to self-pollinate these selections for several generations to determine whether self-pollination reduces the vigor and whether they will remain relatively true to type. Yields were secured from

certain self-pollinated, open-pollinated, and vegetatively-reproduced strains of orchard grass in 1927. The results are being compiled. A paper pertaining to this experiment has been issued under the title: Further Studies of the Pollination of Orchard Grass. Jour. Amer. Soc. Agron. 18:1121-1127; 1926.

Rotation Experiment

The results of this experiment are reported in our Bulletin 253. It appears from these results that the best rotations for the section are those of three or more years' duration in which biennial legumes are used for hay production and soil improvement. Short rotations in which annual legumes were used as cover crops failed to maintain soil nitrogen.

Silage Experiments

The results of these experiments are reported in our Bulletin 227. These results showed that corn was superior to sorghum, soybeans, cowpeas, and sunflowers for silage purposes. It was also found that the prolific or ensilage varieties of corn produced a larger tonnage of silage and a larger amount of protein to the acre than the grain varieties. However, the percentage of protein and fats in the grain varieties was slightly higher.

In ensilage varieties, the proportion of silage to grain was three bushels of grain to each ton of silage. In the grain varieties there were five bushels of grain for each ton of silage.

PROGRESS AND RESULTS OF INVESTIGATIONS IN AGRICULTURAL ENGINEERING

By D. C. Heitshu

Research in agricultural engineering was begun by the department in 1922. The first work undertaken was a study of farm water power developed by small streams. This study was made in southwestern Virginia in the counties of Montgomery, Wythe, and Washington. It consisted of a survey of typical farm streams to determine just what power was being made use of, and the energy wasted but which could be utilized economically to generate power. The determination of the best methods of using this wasted energy was also included in the investigation. The data secured from this study were compiled and published in United States Department of Agriculture Farmers' Bulletin Number 1430, "Power for the Farm from Small Streams." Judging from the requests for this bulletin, it has proved very popular and the results good, if the number of small hydro-electric plants recently installed in the State may be used as a measure.

A drainage investigation was begun in 1923. This study was made in Tidewater Virginia, and extended over a period of two years, being completed in 1925. This study was primarily an economic one, involving such features as the actual economic returns from drainage, factors influencing the success or failure of underdrainage, depth and spacing of tile in different soils, etc. This work was conducted by survey method in Accomac and Northampton Counties, Virginia, in cooperation with the Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture. This survey involved 75 farms, 31 in Accomac County, and 44 in Northampton. Slightly over 30 per cent. of the land in the farms surveyed was classed as wet, which would indicate a total of approximately 60,000 acres of wet land in these counties with 2,600 to 2,900 acres of this thoroughly drained. Tile underdrains were used almost exclusively, the open ditches being used but little. Tile drainage was found to cost approximately $75.00 per acre, or an average of 685 feet of tile per acre costing about 11 cents per foot installed. Only 5 per cent. of the farmers reported dissatisfaction with drainage, but the survey revealed that about 35 per cent. of the tracts surveyed were growing poor crops on part of the tile drained land. A number of problems requiring further investigation presented themselves during this study, but as the financial depression in agriculture had curtailed practically all tiling activities in this State, these problems were not pursued.

In 1925, studies were undertaken on certain problems in farm machinery and farm power; and in 1926, soil erosion was studied. This investigation of

soil erosion consisted of a personal survey of 50 farms in Charlotte County, Virginia. Erosion of surface soil is very high in many portions of Virginia and control methods are imperative. Proper terraces will effectively prevent excessive erosion, but unless they are constructed with the proper slope, width, and height, they are easily broken through or loaded with sand and silt, making them ineffective. The actual dimensions to recommend are variable, depending upon the conditions under which the terrace is to be constructed, but sufficient data were secured to indicate the range within which the terrace is satisfactory.

In beginning the farm power and machinery work of the station, it was felt that more definite information as to equipment in use, and the specific needs of the farmer should be obtained so that the work could be directed in the most profitable channels. With this in view, "A Survey of Machinery and Equipment Used on Virginia Farms" was conducted. This survey indicated the extent of use of the various machines and equipment upon the different types of Virginia farms, and the economic results from the use of such equipment. The results of this survey indicated that the greatest good would result from a study of the power and labor involved in the production of the major farm crops (corn, wheat, and hay) and of soybean harvesting methods. The possibilities of reducing power and labor costs by use of mechanical power are especially attractive, hence the first work was conducted along this line.

A "Farmall" tractor, which is an all-purpose cultivating type of tractor, was secured from the International Harvester Company and placed in use on the college farm in 1926. This type of tractor proved satisfactory in practically every operation, although in cultivating it was clear that all of the basic requirements for tractor cultivation had not been determined before this cultivator was built. The tractor proved itself capable of doing general farm work.

The tractor cultivating study was continued in 1927 with the object of determining the basic requirements of motor cultivation for Virginia conditions. This study indicated: (1) Double point shovels in 4-shovel gangs are best for conditions found on the college farm; (2) self-leveling gangs are essential for rolling topography; (3) a master lift lever is desirable; (4) a gang shift in connection with the steering gear may cause hard steering on a side hill; (5) an irreversible steering gear with pivotal steering is desirable; (6) the lateral stability of the tractor should be improved on side hills; (7) the cultivator must be adaptable to various width of rows; (8) the cultivator shields should be improved; (9) the mounting and unmounting of the cultivator attachment should be simplified. It is hoped that the tractor companies will incorporate all, or at least some, of the improvements suggested to them by this station.

A study of the combine harvester-thresher was begun in 1927. This work was done in cooperation with the United States Department of Agriculture. The harvesting of small grains and soybeans was studied, and the combine

was found to be a satisfactory machine, but needing a few changes to meet Virginia conditions. To cut the full length of straw, either to save it or to get all of the lodged grain, a shorter cutter-bar and greater separator capacity are required. Stouter reels are required and other minor mechanical changes are necessary to make the combine fully meet the needs of this State. The combine manufacturers have responded in a most gratifying manner to the suggestion for improvement resulting from this work. The problems of proper harvesting time and storage methods remain to be studied. Considerable progress in this direction is expected during the present year.

The combine proved to be the best soybean harvester now available, with an average loss of 11.7 per cent., or one-third of the customary loss. The same mechanical improvements recommended for small grains hold with soybeans and in addition reduced cylinder speeds and increased separator speeds were found advisable. The correct cylinder speed for soybeans is a problem to be solved. The storage of soybeans requires no attention as the beans come from the harvester in good storing condition.

The cooperative project with the dairy department in feed grinding is the only rural electrification project in actual progress under the Experiment Station at the present time. V. R. Hillman is in charge of this work. This project should yield valuable information during the ensuing year as the feeding experiments will have progressed far enough to make interpretation of results possible.

PROGRESS AND RESULTS OF INVESTIGATIONS IN THE DEPARTMENT OF AGRICULTURAL ECONOMICS

By J. J. Vernon

The station began investigations and research work in agricultural economics in 1923. Research and experimental work in the field of production had been advanced to a helpful stage and there was a keen need on the part of the farmers for assistance on the business side of farming. Our work in agricultural economics was undertaken for the purpose of meeting this need.

A Study of Tobacco Farms

By the Survey Method.—The first project undertaken was a study of farm organization and the relationship of farm enterprises with special reference to the place of tobacco in the farm organization; and this project was carried out in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture in order to give tobacco farmers of Virginia definite information as to why some farmers were making more satisfactory returns than were others, and to show from the results of the actual farm experience of a large number of tobacco farmers the most important ways in which they could improve the effectiveness of their farming and increase their income.

Some 138 bright tobacco farms in Pittsylvania County and 150 dark tobacco farms in Appomattox County were studied by the survey method. A careful record of all farm operations were obtained for each farm. Besides securing the acres and yields of crops grown, the number and value of livestock on hand at the beginning and end of the year, and data as to the farm itself, a complete record of receipts and expenses were obtained from which a financial statement was computed for each farm showing the net returns for the crop year ending March 1, 1923. A detailed report and the conclusions arrived at were published in our Bulletin 241. It was found that with dark tobacco legumes and fertilizers increased the yields of tobacco. Fertilizers not only increased the yield but also improved the quality of bright tobacco as measured by the selling price per pound. Quality and yield influence the per acre value; and per acre value and the number of acres in tobacco are the dominant factors in net returns from the tobacco enterprise. However, in this connection, it should be pointed out that there is a limit to a profitable increase in tobacco acreage per farm, since the operator's earnings per acre of tobacco consistently decreased with the increase in tobacco acreage.

It was found that as the family use of farm products increased, the net farm returns increased within certain limits. Farmers therefore should give

attention to the production of garden vegetables, milk, meat, and fruits for home use, rather than to purchase these products out of the income from the sale of tobacco, thus saving the items of cost of transportation and the middleman's expenses and profits.

The effect on the whole farm business of the farm operator's managerial ability is shown at many points where there was opportunity for choice. One conspicuous example is found in the efficiency of farm management, measured by the amount of operator's earnings, when applied to farms of different size, as measured by the number of acres under cultivation. The average operator's earnings (the pay the farm operator reecives for wages as laborer, salary as manager, and profit, if there is any) was 33 per cent. larger with the large than with the small farm business. However, it was shown that, on these farms, managerial ability was more effective in increasing the gross returns from production than it was in reducing the cost of production. Gross income from products increased 128 per cent. from smallest to largest size of farms in the dark tobacco belt, while expenses increased 238 per cent. on the same group of farms. In the bright tobacco belt the differences were still greater. Owing to the fact that expenses increased very much more than income, the increase in operator's earnings was reduced proportionally, thus indicating specifically where the exercise of managerial ability is likely to be most effective.

Because some workers in agricultural economics have not been satisfied with labor income as a measure of success in farm management, for the reason that it did not include the items furnished by the farm for family use, using the data secured in this study, a statistical test of the measure of farmer's financial success was made. The results of the multiple correlation showed that operator's earnings (which include items furnished by the farm for family use) is a better measure of the farmer's financial success than either labor income or labor income plus the family-used items. The results of this test should be of value to farmers indirectly, but of more direct interest to research workers.

By the Route Method.—On March 1, 1922, about a year and a half before the department of agricultural economics was organized, the Extension Division of the V. P. I., in cooperation with certain banking institutions in Virginia and the Bureau of Agricultural Economics of the United States Department of Agriculture, began a study of the tobacco enterprise by the route method and continued the study for two successive years. Thereafter a few farms were selected for testing certain recommendations. The results of this study were published in our Bulletin 255. Daily records of all the operations for the tobacco enterprise were kept, including man labor, horse and machinery work, income and expenses; and from these various items a statement of quantity and cash cost of producing both dark and bright tobacco per acre was prepared. For only four or five farms the same results were obtained for all

the farm enterprises as well as tobacco. Charts were prepared showing the distribution of man labor and horse work by 10-day periods for the separate enterprises and the whole farm for a typical dark and typical bright tobacco-growing farm, thus providing for enterprise adjustments so as to effect a more efficient utilization of labor. The outstanding contributions shown in this publication are: (1) quantity and cash cost of tobacco production, (2) charts showing the distribution of man labor and horse work, and (3) the material upon which was based the outlook report for dark and bright tobacco.

The Farmer's Home Market

The project, "The Agricultural Situation in Roanoke and Its Trade Territory," conducted in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture, was the first study made in Virginia on the marketing of farm products. In this study an attempt was made to translate the advantages and disadvantages of local producing areas into concrete terms. The farmer has three principal outlets for farm products: (1) home consumption, (2) the local city market, and (3) distant or foreign markets. There should be a clear understanding of the relationship between these methods of disposing of farm products. Products consumed by the family are marketed without transportation cost. Products consumed on the farm by livestock and sold through the various kind of animal products — milk, butter, eggs, and meat — afford a saving in transportation costs, whether sent to the local or distant market, with the same local haul in either case. However, if shipped to a distant market, transportation charges, commission, etc., must be deducted from the selling price. Selling on the local market compels the distant producer, if he would compete on the local market, to pay the freight. It reduces itself to competition either at home or abroad; but the home market may have certain advantages which the local producer should not neglect until he has clearly demonstrated that, with his soil and climate and personal ingenuity, he is unable with profit to compete thereon with the distant producer.

In view of these facts a close adjustment of local production to local market demand seems particularly advisable for the local producer. In order to accomplish this for Roanoke and its trade territory the market situation was critically studied. Data were assembled showing the per capita consumption, the source, quantity, and timeliness of supply and the transportation charges by commodities. Furthermore, since the producer must be placed in possession of some measure upon which to base plans for the future, a historical record of what occurred on the city market during past years in the way of growth in population and trends in purchasing power as indicated by bank deposits, building permits, postal receipts, number of industrial employees, size of wage payrolls, etc., were secured. The information was published in our Bulletin 240. Some of the more important deductions were as follows:

1. Increased freight rates since 1920, improvement in roads and means of transportation, and the growth of the city of Roanoke during the preceding five years, increased the advantage which local producers have over outside producers in supplying the home market.

2. No increase in the production of whole milk for fluid milk consumption, except to meet the growth in population is warranted until the per capita consumption increases, which at the time of the survey was very low.

3. Poultry and egg production may be increased considerably without noticeably affecting the price.

4. An increase of early and some late vegetables was warranted. By storage there was opportunity of increasing the marketing of more than 400,000 pounds of cabbage from the Bent Mountain district between December 1 and April 30. Railroad receipts of potatoes were 60 per cent. of the total year's sales during October and November and 40 per cent. during December and January. The increase in freight rates on potatoes from Minnesota in 1920 gave the local growers a differential in their favor of from $14 to $16 per acre on a production of from 113 to 132 bushels per acre.

5. Feed for stock is shipped in from outside the territory. Outside the dairy sections increase in the number of sheep would prove profitable.

6. The average apple pack in this territory is low.

Renting Farms in Virginia

Information regarding the terms and duration of rent contracts were obtained in 1925 by questionnaire from several hundred landlords in practically all the counties in Virginia, in a project carried on cooperatively with the Extension Division of this institution and the results published in our Bulletin 249. The distribution and growth of tenancy of the various types— (1) straight share, (2) croppers, (3) cash, (4) stock share, and (5) standing-rent — are shown. It was found that lease contracts should be written in order to avoid disputes and in consideration of soil fertility maintenance, should preferably be for several years' duration. All leases should be based upon what each party puts into the business. A sample lease contract is given.

Dairy Farming in the Shenandoah Valley

This project, a study of the organization and operation of farms in the Shenandoah Valley, with special attention to the dairy enterprise, was undertaken in cooperation with the department of dairy husbandry of this station and the Bureaus of Dairying and Agricultural Economics of the United States Department of Agriculture, for the purpose of discovering the reasons why some farms are more profitable than others, and to indicate ways in which farmers may increase their net returns. A report of the results and recommendations are published in our Bulletin 257.

Complete records of all the farm operations were secured for 287 farms in Augusta and Rockingham counties, of which 248 farms produced some dairy products, 25 were beef farms, and 14 poultry farms. A financial state-

ment was prepared showing the average income, expenses, and net returns by types of farms — dairy, crop-dairy, beef-dairy, hog-dairy, poultry-dairy, truck-dairy, small dairy, beef, and poultry.

Operator's earnings is the net pay received by the operator of the farm for his labor and management after all other items have been cared for. Wide variations were found in operator's earnings for the different farms included in the study, as is shown by a comparison between the averages between the 44 best and the 44 poorest paying farms. The 44 best of the 220 dairy farms received an average operator's earnings of $1,777, ranging from $1,161 to $4,624; and the 44 poorest farms yielded no operator's earnings — on the contrary, the results from the 44 poorest farms showed an average loss of $467 per farm. The reasons for these variations are pointed out and illustrated in the bulletin.

It was found that livestock was the largest producer of income, and productive efficiency of livestock was the most important factor affecting net farm returns. To illustrate, operators whose livestock were only half as productive as the average in this area lost $380 by their year's work on the average, whereas operators whose livestock were twice as good as average made $1,960 on the average. Profitable dairying depends to a large extent on high production per cow. In this study the value of products per cow varied more than $125 between low and high producers.

Crop yields were second in affecting net farm returns. Farms with yields 50 per cent. better than the average for the area, and with livestock of only average quality, made $1,200 operator's earnings, while farms with yields 50 per cent. below average, and with average livestock, returned only $180 operators' earnings. The variations in yields from farm to farm are due to several factors, but probably the most important is that of the cropping system followed. The system of crop rotation that provides for the maintenance of the humus content of the soil and includes a large percentage of legumes proved the most profitable.

Since productive efficiency of livestock was the most important factor affecting net farm returns and crop yields were second, as would be expected, it was found that combined livestock and crop efficiency affected net farm earnings to a marked degree. Farms with both livestock and crop yields twice as good as average made operator's earnings of $2,530; whereas farms with both livestock and crop yields only half as good as average lost $830 for the year's work.

Furthermore, it proved more profitable to sell crops through beef cattle and dairy cows than through direct sales, beef cattle proving slightly more profitable than dairy cows of the quality kept. Feeding crops to livestock on the farm saves the expense of hauling them to market, provides profitable employment for labor during winter and slack seasons, and since only about one-fifth of the plant food contained in the feeds consumed is retained in the

animal body, helps to maintain soil fertility, provided both liquid and solid manure are conserved and returned to the soil.

Some of the other important factors that were found to influence net farm returns were as follows:

1. Size of business;
2. Acreage of improved land, crops, and open pasture;
3. Larger per acre yields of corn, oats, and legume crops;
4. Larger proportion of silage and legume crops;
5. Larger number of cows, young dairy cattle, sheep, lambs, and poultry;
6. Rations fed and nutritive ratio;
7. Efficient use of machinery, man labor, and horse work, providing for effective employment during wet weather and slack seasons.

The facts set forth in this bulletin clearly demonstrate that managerial ability of the farm operator is the motivating force behind every factor affecting net farm returns and that there is ample opportunity for improvement in farm management in this region.

Beef Cattle Farming in Southwestern Virginia

In view of the situation confronting the cattlemen of southwestern Virginia, owing to the shifting in market demands for grass-finished beef in recent years, a study of beef cattle farming was begun in 1924, in cooperation with the Bureaus of Animal Industry and Agricultural Economics of the United States Department of Agriculture.

By the Survey Method.—The first project was planned to study the cost of production and the methods, practices, and costs of marketing Virginia cattle; to ascertain the market grade, dressing percentage, the carcass grade, and the relative demand for grass-finished beef as compared to that produced in other competing sections, and to determine to what extent conditions could be improved. The results of this study will appear as a bulletin of the United States Department of Agriculture.

By the Route Method.—A further study of beef cattle farming in southwestern Virginia was continued by the route method between the same cooperating parties, covering the crop year of 1926. The department of animal husbandry of this station collaborating in this study, began in the fall of 1925 a series of feeding experiments with beef steers of the type found in this region. The earlier studies indicated that the methods of handling cattle followed on most farms are largely patterned after the methods in vogue when there was an export demand for large, heavy steers, but that several other methods were being tried by some cattlemen. This study was planned to test the advantages and disadvantages of each method and the changes in the systems of farming that will likely be more profitable.

Daily records were made of all the farm operations, including an inventory at the beginning and end of the year, income, expenses, man labor, horse

work, etc., for thirteen farms and the same data only for the beef cattle enterprise for an additional 25 farms.

The results of this study were published in our Bulletin 258, which shows financial statements giving the details including receipts, expenses, and net returns for: (1) five selected farms; (2) suggested systems for five 400-acre farms; (3) suggested systems for five 300-acre farms; (4) charts showing the man labor and horse work by enterprises and the whole farm for one typical farm and for two 400-acre suggested systems; (5) normal returns from beef cattle of different ages, handled in different ways; and (6) data upon which to base plans for the future.

It was found that cattlemen of southwestern Virginia are in a large measure producing the type of cattle demanded by the export trade 15 to 20 years ago. This type of steers does not command the premium it did formerly, owing to the changes in the food habits of many of the people. An earlier maturing type of cattle appears to offer better opportunities for profit than the type generally handled. Two-year-old steers are suggested for at least a fair share of the farms where sufficient land can be devoted to growing sufficient grain for the necessary supplemental feeding, in order to smooth out somewhat the mid-season (October) peak marketing load. On these farms, barley, a feed crop, is suggested as a partial substitute for wheat.

Young cattle have not been in demand heretofore for finishing purposes; and therefore the short, blocky, early maturing type with well defined beef breeding is scarce. It was found that cattlemen have paid little if any more for the blocky, early maturing type than for the rangy, late maturing type; therefore, there has been no incentive for the feeder-producer to supply them. No change may be expected until a premium is offered for the improved class of feeders. The effect on market price of a change to a younger and better bred type of feeders, if sufficiently general over the whole region, should not be confined to the younger type but should be reflected in somewhat improved prices for the heavy type as the seasonal peak is leveled out.

Factors Influencing the Yield of Apples

Distress among the apple growers of Virginia has been widespread in recent years. This was shown to be at least partly due to over-planting during earlier periods of higher prices. In order to reach an intelligent decision or to avoid similar difficulties in the future, an understanding of the underlying causes of the present economic distress and the future possibilities of the apple industry are essential. Accordingly, the project "An Economic Study of the Apple Industry in Virginia" was begun in 1925 in cooperation with the experiment stations of West Virginia and Pennsylvania, and the Bureau of Agricultural Economics of the United States Department of Agriculture, and it covered the Cumberland-Shenandoah region. The Piedmont region was included in the Virginia part of the study. This project falls naturally into

three principal phases: First, factors influencing the yield of apples; second, improvements that can be made in the marketing of apples that will increase the net returns to the grower; and third, orchard management and the place of the orchard in the farm organization.

The results of the first phase of the study were published in Technical Bulletin No. 54 of the United States Department of Agriculture. There are many factors influencing the yield of apples as shown by the following list:

1. Varieties (number of trees);
2. Planting distance;
3. Stand (missing trees);
4. Frost;
5. Temperature, February 7 to March 21;
6. Air drainage
   (a) Elevation above surrounding land;
   (b) Grade of slope;

Exposure
   (a) Protective barriers;
   (b) Direction of slope;
8. Off-year;
9. Pollination (failure to set);
10. Drought;
11. Hail;
12. Wet weather;
13. Insects and diseases;
14. Soil;
15. Cultural practices
   (a) Sod,
   (b) Tilled,
   (c) Fertilizers,
   (d) Pruning,
   (e) Spraying;
16. Yield per tree.

The following conclusions were drawn from the information gathered:

(1) The region as a whole is well adapted to apple growing, but intelligent choice of soil and site is essential to success.
(2) Cultural practices average far below the standards that are essential to success, and losses actually due in part to poor practices which might easily be overcome with good practices and proper measures for disease and insect control, are often attributed to frost and off-year.
(3) Unless the elevation and air drainage are unusually good, abnormally high temperatures during the period from February 7 to March 21 almost invariably cause bud development to such an extent that injury by frost or freezing later in the season is almost certain, resulting in low yield.
(4) Depth of soil is essential and, therefore, strata of rock near the surface should be avoided.
(5) Low-yielding trees should have special attention — they affect the profits.
(6) Sites exposed to cold winds, pockets in the surface from which air cannot drain away, and sites on the leeward side of mountain gaps should be avoided because of a tendency to excessive injury by frost, freezing, and hail.
(7) An outstanding error in setting orchards has been too close planting — 40 by 40 feet is the minimum distance indicated.

(8) Failure of fruit to set, in some orchards, was the result of planting self-sterile varieties in solid blocks or isolated from other pollinizers. Every fourth tree, alternated, should be set with a known pollinizer.

(9) Nearly fifty varieties of apples were found in the region and in some cases as many as fifteen on a single farm. Economy of production would dictate a small number of commercial varieties in greatest demand.

A Study of Dairying Near Richmond, Virginia

Because of transportation costs the city of Richmond draws the bulk of its fluid milk supply from a comparatively small area near the city. The standards for grade and quality set by the city health officers multiply the difficulties that must be met by the producer. When the producer shifts from the production of milk for factory uses to that of milk for fluid uses, a new set of economic factors appears which may necessitate a complete reorganization of the farm business and certainly will require readjustment of enterprises and methods of operation. Because of the difficulties under which the fluid milk producer is operating, the project, an economic study of the production, disposition, and consumption of milk and milk products for the city of Richmond and its fluid milk supply territory, was undertaken in cooperation with the department of dairy husbandry of this station, the Bureaus of Dairying and Agricultural Economics of the United States Department of Agriculture, in February, 1927, to be continued as many years as should prove desirable.

The project naturally falls into two parts: First, a study of dairy farms and factors affecting economy of dairy production in the dairy area in the vicinity of Richmond; and second, the disposition and consumption of milk and milk products in the city of Richmond.

The first part is being continued with such changes as were found necessary in order to make certain tests. The second part has been completed and the results prepared for the printer. It was necessary in order to indicate to producers the trend of consumers' demands as related to the dairy industry, to determine the supply and consumption of milk and milk products in the city of Richmond for a number of years. Furthermore, the producer must plan ahead as best he can to take care of future demands on his business and, therefore, an analysis of factors influencing consumers' demands was made, based on trends in city population, post office receipts, clearing house exchanges, debits to individual accounts, and building permits.

It was found that Richmond is over-supplied with fluid milk of the grade and quality required by the city health officers under the present per capita consumption of 0.404 pints per day. Milk that meets the city standards costs more to produce and also brings a higher price than milk produced for factory purposes. Since the high cost of surplus milk must be converted into other milk products it comes into direct competition with the low cost factory milk and, therefore, may bring no more than factory prices.

The per capita consumption of milk in Richmond is low, 0.404 pints per day, as against 0.741 pints per day for New York City, indicating a possible outlet for surplus milk through effective advertising and educational campaigns, showing comparative food values and the importance of milk as a food for growing children.

INVESTIGATIONS IN THE DEPARTMENT OF RURAL SOCIOLOGY

By W. E. Garnett

The department of rural sociology was organized August 1, 1925. After consulting with a number of agricultural leaders, and carefully considering the relative importance of the many social problems affecting Virginia rural life in need of investigation, a study of "Rural Organizations in Relation to Rural Life in Virginia" was chosen as the first field of investigation. It was felt that since organized effort is so important to the welfare and progress of every great social group, it is well for those concerned with rural life to take stock from time to time to see whether: (1) the needs of the ever-changing situation are being met in a well-balanced way; (2) to note the strong point and the weak of the organization methods and policies being followed; and (3) to analyze the factors which must be taken into account in a successful rural organization program.

A series of studies designed to throw light on these questions was therefore planned — a series which will take at least five years to carry to completion. Such a big problem as "Rural Organizations in Relation to Rural Life in Virginia," of course, has many aspects. It was, therefore, necessary for purposes of study to break it up into a number of sub-units. The first unit, on which one bulletin — Va. Agr. Exp. Sta. Bulletin 256 — has already been published, gave especial attention to the attitudes of the people themselves toward organizational questions. This study was also intended to serve as a general introduction to the prevailing organizational situation and the many complex questions which it involves. It was planned to follow this rather general study by more intensive studies of particular aspects of the field. These more intensive studies are to include investigations of the activities and accomplishments of various types of adult and young people's organizations; intensive studies, together with some experimental work, in the field of community organization and development; investigations of the rural church situation; of fairs; and of the activities of town organizations in behalf of country life.

The units on young people's organizations; community organization and development; and the rural church are now in process of being worked out; and should reach the publication stage within a short time. A committee of church leaders from the seven largest denominations of the State have cooperated with the station's representatives planning and carrying out the study of church young people's organizations and the rural church. The department has also been fortunate in having the closest cooperation and sympathetic counsel of the V. P. I. Agricultural Extension Service, and the State Depart-

ment of Education, in its study of 4-H clubs and other young people's organizations related to the schools.

Prevailing Organizational Conditions

The study of the organizational situation in rural Virginia, as it has progressed thus far, has brought out many significant facts. It was found that:

There is much more organizational activity going on than the majority of people realize. Furthermore, such activity is on the increase. This is particularly true in the field of commodity marketing organizations which together handle between fourteen and fifteen million dollars worth of produce a year.

As yet, however, a comparatively small percentage of the people take part in organizational activities. In fact, only about 13 per cent. of the farmers of the State are selling cooperatively and less than 25 per cent. are buying by this method. In terms of value of product, moreover, only approximately 8 per cent. enters the market by the cooperative route, while less than 2 per cent. of farm supplies are purchased in this way. Furthermore, less than 5 per cent. of the farmers belong to a general type farm or educational organization. There are no farmers' organizations in the State strong enough to adequately deal with State-wide questions calling for organized effort. Lack of more general support of organization effort appears to be due to the fact that people generally have not realized the importance of the problems needing group effort, and to the fact that they do not generally know the best organizational procedure for meeting these problems. These conditions, in turn, are due to the failure of the educational system to give needed instruction along these lines, as well as the failure of such molders of public opinion as editors, preachers, teachers, county and home agents, and organization officials, to keep the questions calling for group effort and the best organizational procedure continuously before the public. In fact, the evidence brought out in the study forces the conclusion that rural organizations are not receiving the support from various public opinion-forming agencies, that the importance of the work they are attempting to do justifies. This situation is in a large measure responsible for unfavorable organizational attitudes.

Lack of organizational support can also be traced to the general prevalence of deep underlying attitudes, or "behavior patterns," such as conservatism, individualism, resignation, and spirit of fatalism, credulousness and lack of the scientific spirit — attitudes which grow out of the socio-economic environment and occupational experiences of farm folk. Insufficient and ill-adapted education; constant struggle with little understood, and uncontrollable natural, economic, and social forces; narrow margin of operating capital; meager contacts; and lack of sufficient devoted leadership with knowledge-

tempered vision — all these are factors in determining behavior and must be dealt with more effectively before organizational effort reaches full success.

While most people profess to be believers in cooperative effort, the majority do not appear to have fully realized that such activities will not succeed automatically; and that if they are to receive the fullest returns from such undertakings they must pay the price of continuous loyal support. A full realization of this point is especially important for members of marketing organizations. The study showed clearly that any organizational effort which runs counter to a long-established system can expect to meet with much opposition, both direct and indirect, especially if large vested interests are involved.

The study also brought out that there is not sufficient team pull between the different types of organizations devoting themselves to rural life problems. The great amount of duplication of effort, lost motion, and failure of organizations to reach their objectives, also play a part in weakening confidence in such activities.

It was found, furthermore, that comparatively few realize the advantages present day organizations have over the ones which so generally failed in the past. The lessons which present day organizations can learn from half a century of organizational experience are not generally appreciated; neither is it generally realized that present day organizations have a great advantage over those of the past because of the many types of governmental aid recently developed.

It was found, moreover, that publicly-supported institutions with their paid workers are playing a larger and larger part in the organizational situation.

Rural Organizations Not Meeting Their Responsibilities

A study of the existing organizational situation in the State indicated that though many individual organizations are doing good work the organizations taken as a whole are not measuring up to the challenge of their opportunities and obligations. An analysis of this phase of the problem indicates that among the State's problems which appear to demand attention in an organized way, the following seem to be of outstanding importance: Raising the general level of farm incomes; eliminating the many inefficiencies in agricultural practices; putting the whole marketing system, both buying and selling, on the most efficient basis; eliminating habitual attitudes and behavior patterns adverse to cooperative action, and making more common the attitudes favorable to the general application of available scientific knowledge; speeding transitions and adjustments in types of farming of each region to meet changing labor, transportation, and market conditions; making electric power more generally available for various farm and home purposes at least cost; developing community consciousness and speeding the re-crystallization and development of broken-down neighborhood and community centers into larger and more effi-

cient community units; providing for an educational system which will adequately prepare rural people for the most efficient work and most abundant lives; providing for adequate public library facilities in each county and community and encouraging their use; stimulating and making possible the home surroundings and standards of living necessary for family efficiency, full personal development, and greatest life satisfactions; providing for wholesome recreation that will compete on equal terms with commercialized amusements; securing a just tax system, a system that not only does not take an unjust share of his income from the farmer, but also one that will insure sufficient public revenues to adequately provide for schools, roads, public health work, hospitals, and libraries — these are some of the outstanding things pressing for organizational attention. Or at least so it would seem from interviews with many farmers and organization leaders in every part of the State, and confirmed by an analysis of numerous statistical reports.

All these things call for vigorous, systematic, unified effort on the part of all types of organizations interested in a satisfying country life.

The rural sociologist believes:

That a scientifically efficient civilization is one in which all forces make a unified, systematic, well-planned, vigorous effort to put into general use all available scientific knowledge on every problem of social concern.

That it is no longer necessary to leave social progress to blind chance; but that it is now practicable to set definite standards or goals as socially desirable — standards as to educational attainments, health conditions, home surroundings, agricultural practices, marketing methods, and so forth, through the whole range of community life.

That through a well thought-out, long-time program based on the solid rock of exact fact, rather than on the sand of conjecture and theory, it is possible with unified effort to reach the goals which have been agreed on as socially desirable.

That with the recent rapid developments in natural and social sciences, and the rise of many State and national public service institutions and agencies, it is now feasible for organized groups to solve almost any problem with which they may be confronted, and to carry out any program which they may have the vision, the courage, the initiative, the energy, and the will to undertake.

If the sociologist's view is correct, a candid facing of the facts brought out in this study forces the conclusion that Virginia rural organizations are not fully meeting the challenge of their obligations to Virginia rural folk.

Undoubtedly, one of the first steps before organizations will, or can, successfully meet this challenge is more systematic study by country life leaders — county and home agents, teachers, preachers, editors, and organization officials, as well as, through their influence, by the rank and file of the people of the available literature dealing with the various social and economic questions

now confronting country life; questions which constantly grow in numbers and complexity, and which demand increasingly more involved and far-reaching methods of solution; questions that ignorance is utterly incompetent to deal with. This is the outstanding conclusion of our organization study to date.

Virginia Agricultural Experiment Station Bulletin 256, "Rural Organization in Relation to Rural Life in Virginia," the first publication in our organization study series, has been widely read and studied by rural community leaders and organization officials. It has greatly quickened interest in the problem of more effective organization and stimulated efforts in this direction. It has also been used as a supplementary text in social science courses in many of the colleges and high schools.

Community Development Study

An important unit in the rural sociology investigation program is a study of the changes going on in community life and the principles of successful community organization. This study has not yet been completed, so only a brief preliminary report of findings can be given.

The local community is the foundation of the whole superstructure of satisfying rural life. Local community conditions, facilities and relationships are the questions of immediate concern to the majority of people and the ones which most vitally affect their lives. Consequently, an understanding of the principles on which to base successful community building programs is a matter of the greatest importance. The development of efficient community units is one of the chief responsibilities confronting all rural organizations. In fact, one outstanding authority on country life even goes so far as to say that "The building of real local farm communities is perhaps the main task in erecting an adequate rural civilization."

By community, we mean that area where the majority of the people are definitely conscious of mutual interests and concerns; are in the habit of associating together for several common purposes; and have a well-developed spirit of loyalty to the common center and its institutions. In a neighborhood the area embraced and the number of families are smaller than in a true community and the common interests are fewer and usually less highly developed.

The study of community development trends indicates that many profound changes in community life are now going on. Among the most significant of these are: (*a*) the tendency of small neighborhoods to break up — a tendency traceable to the improvement of roads and the general use of the auto, consolidation of schools, transference of trade to larger centers, and free delivery of mail; (*b*) the tendency for town workers to have their homes in the country; and (*c*) the tendency to substitute commercialized recreation of the towns for the old types of neighborhood sociability.

It was found that the disintegrating neighborhoods have not generally as yet recrystallized into larger and more efficient community units. This condition appears to be due to a failure of local leaders to recognize the necessity of readaptations to meet changing conditions as well as to a failure of the organizations and institutions of the larger centers to fully appreciate their responsibilities to the larger community area, and to draw people from the whole area into their activities.

A large percentage of the town workers who live, and occupy space and property, in rural areas do not actively participate in rural community life; but have their social and institutional life in the towns where they work. Consequently the community strength tends to become divided and the struggle to keep local community or neighborhood institutions and organizations going becomes more acute, especially if local leaders thus transfer their allegiance.

Recreational activities, by promoting acquaintanceship and mutual confidence, have from time immemorial been a basic foundation for group action. The tendency to substitute commercialized recreation of the towns for the old types of neighborhood sociability almost entirely eliminates this group cementing force.

Churches and other voluntary organizations have not generally responded to the changed transportation situation with an enlarged membership area as has generally been the case with the schools.

The data gathered on community conditions and changes indicated that if satisfactory progress is to be made in the various phases of community life there must be more united support by all groups of systematic long-time plans of development based on all available technical assistance. This is the most important principle of community development procedure so far developed by the community study.

The Relation of the Rural Church to Rural Organizations

The rural church study is also not yet completed. Hence only a brief summary of some of the most important facts so far developed can be given.

If the view is correct that satisfactory community development, and efficient organizational effort, must be based on more intelligent public opinion; and on a more widespread sense of responsibility for the common good, the rural church has, or can have, an important part in promoting effective rural organizations. Furthermore, the church and its affiliated societies absorb a large percentage of the organizational time and energies of rural folk. The executive officers of church boards and other church leaders are coming to the conclusion that the changes now going on in rural life will sooner or later force them to decided changes in their rural church policies. More facts about the situation, as a whole, which is difficult for any single denomination to get, would help in the formulation of such new policies. For these reasons it was

felt that a study of the rural church, and some of its affiliated groups, especially the young people's religious organizations, should be important units in any program of organizational investigation.

There are about 6,000 rural and 1,000 urban churches in Virginia. The average strength of the rural churches is 118 members, half of which are estimated to be inactive. A very large percentage of these churches fall far below the average. The average membership of city churches — including active and inactive — is 585.

There is one rural church for every 300 rural people, and one urban church for every 750 urban people. Furthermore, only about 45 per cent. of rural people are church members; while about 60 per cent. of urban people are church members. As a rule village churches include few farmers in their membership.

The average rural church raises about $1,300 a year for all purposes, while the average for town and city churches is around $12,000. The average annual per capita contribution of rural church members is $11.00, as compared to an average of $21.00 for the town church members. In this connection, however, it should be remembered that the per capita wealth of Virginia urban dwellers is estimated to be almost three times that of Virginia farm folk.

The church study reveals that one of the main troubles with the struggling rural church is that adjustment to new methods of transportation has not been made at all or has been made too slowly. In one case, which is typical, four churches of the same faith were found on a State highway within eight miles, or a fifteen-minute drive, of each other. The combined membership of the four was only 550, not more than enough for one strong church. If consolidation of such groups of churches ever comes, the small rural village will probably be the center for the newer and stronger church. But here it should be mentioned that, at present, for some reason, farmers stay away from village and town churches — except in unusual cases.

Rural Life Problems and the Program of the Church

Is the rural church and its ministry equipped to bring to bear on rural life problems the best religious thought and effort of the day? Obviously not. Low incomes for ministers — due to too minute subdivision of the field; part-time, absentee ministers; and other conditions make it practically impossible for the church to measure up to its opportunities and obligations. The present leadership of the rural church, for the most part, has been trained along conventional lines of church work; thus getting no knowledge or vision of the relation of the church to community welfare.

The rural church is in a position to be of great service to the public schools, agricultural extension work, public welfare, public health movements, recreational activities, libraries, and community organizations. These movements make up the machinery through which rural people can obtain the

things that the preachers of several generations have said that rural people need. Already there is a fine spirit of cooperation between the churches and such movements as those mentioned; but all too often rural ministers are missing great opportunities of service in not actively supporting and encouraging such movements. In a few cases, ministers have actually been a hindrance to the above programs of work.

Young People's Religious Organizations

Young people's religious organizations have had a tremendous growth during the last twenty years and are doing some very good work. Their program of training young leaders and of furnishing wholesome recreational and social life for young people of the community is very laudable. However, few small rural churches are successful with these organizations. The smallness of the church and the lack of competent, interested leadership are two of the main causes of failure. Many young people, who would otherwise make good leaders, either go away to college, or go to the city to work. Ministers take the lead in many cases; and where they do so, they are adding a great deal to the value of the rural church. On the other hand, not all ministers were found to be as enthusiastic about young people's work as they are about the traditional program of the church. Furthermore, some ministers are not popular with the young people because of their attitudes on recreational and amusement questions.

The results of a simple Biblical and ethical test administered to high school pupils, college students, and to Sunday school teachers show in a vivid way the inefficiency of the present program of religious education in the Virginia rural church. Poorly trained teachers, no trained directors of religious education, poor equipment, and a thirty-minute class period once a week, account in part for low scores made on the tests given to something like three thousand people over the State.

Use of Survey Results

Seven denominations are cooperating with the Agricultural Experiment Station research workers in making the survey or study of the rural church. Already several of the larger denominations have special committees appointed to study more thoroughly the facts made available by the survey and will in time make recommendations to their respective church bodies concerning future policies and programs.

Undoubtedly, there is a strong tendency for more inter-denominational cooperation today than ever before in the history of Protestantism. The old antagonistic attitudes between religious sects are practically gone. Many instances can be found over the State where local churches have worked out cooperative programs in the same community. But the scars of the last century of sectarianism and denominationalism still remain. Practical methods of

denominational cooperation must be worked out further in order to save the rural church from disaster. A decreasing rural population, consolidation of rural schools, and faster transportation is making cooperation between denominations more urgent and more possible.

Young People's Organizations Study

Rural life leaders are more and more tending to recognize the importance of young people's organizations and activities as the basis for the most desirable rural life of the future. It is highly desirable, therefore, that the work and programs of such organizations shall be as efficient as possible. In accordance with this line of thought, the department of rural sociology has under way a study of several types of young people's organizations, especially those having to do with vocational training like the 4-H clubs, young people's religious organizations, and recreational clubs. This study as it has progressed to date indicates that these organizations are all doing some very fine work and making material contributions to the rural life of the State. It also indicates that they have a number of very weak places in their programs of work. The study has already stimulated efforts to eliminate some of these weaknesses.

INVESTIGATIONS IN THE DEPARTMENT OF HOME ECONOMICS

By Ellen A. Reynolds

Investigations and research in home economics were organized July 1, 1925, after the passage of the federal Purnell Act, which gave additional support to the station. The need has long been felt for research work in this field in order to give to rural home makers more definite facts regarding the problems peculiar to the rural home. During this period of time three projects were dealt with.

Food Expenditures of Farm Families.—The object of this study was to secure definite facts as to the expenditures of rural families for food and as to the relative amount and kinds of the food raised on the farm and consumed by the family. This information is needed as a basis for suggesting improvements in home management and in the dietaries of rural families. Home account books were compiled and distributed to about 200 families. Effort was made to avoid the securing of data from a select group, although since only 73 of the families made accurate records of food expenditures, this may in reality represent a select group, including the more progressive and better educated tenants and farm owners.

According to the records secured from these 73 families, the average expenditure per family for food was about $200.00; and in addition to this, the average family consumed home-grown food products to the value of about $600.00. The proportion of home-grown food entering into the family diet was approximately 75 per cent. The average size of the household represented in these 73 records was 6.8 persons.

Dietary Habits of Rural Families.—A study was undertaken relative to the dietary habits and practices of rural families with a view to improvements and modifications when such seemed advisable. Particular attention was given to the effects of inadequate diets upon the health of the family, especially the health of the children. Cooperation in this study was secured from the public schools at several places in the State and from the Bureau of Child Welfare of the State Department of Health. Over 400 schedules were secured describing the food habits and condition of the teeth of white school children; 50 schedules of pre-school children; and in addition 85 schedules were secured of colored school children from the practice school of the Virginia Normal and Industrial Institute (the latter through the cooperation of President John M. Gandy).

The study showed that only 15 per cent. of these rural school children 6 to 14 years of age had perfect teeth; of the children with perfect teeth, 50

per cent. regularly used 1 pint to 1 quart of milk a day, and 20 per cent. with perfect teeth used at least ½ pint a day. The study also showed a close relationship between perfect teeth and an adequate amount of milk in the diet; for the coefficient of correlation of children having perfect teeth and using 1 pint to 1 quart of milk a day was 0.73 + 0.10. Similar high positive correlations were found between the number of children with perfect teeth and those using green vegetables and fruits regularly in the diet. This study brings out in a convincing way the need for adequate amounts of milk, green vegetables, and fruits in the diet of children in order to insure proper development of the teeth and bones and the maintenance of general nutrition as a whole.

The study also shows that less than half of the children included in this investigation were receiving an adequate amount of milk in their diet.

THE RELATION OF HOUSING TO HEALTH.—The object of this study is to gather information relative to what has been accomplished in other states and countries along the line of legal requirements as to the standards to be observed in building homes; and to study the relation of housing conditions to the health of families in rural sections of Virginia. A field study is being made in representative areas of the State.

PROGRESS AND RESULTS OF INVESTIGATIONS AT THE COUNTY STATIONS

By T. B. Hutcheson

Owing to the wide range in climate and the diversity of soil conditions in Virginia, numerous types of farming are met with in the State. It is not possible to conduct field experiments at one point which will be applicable to all regions in the State. Because of this circumstance, the policy was adopted many years ago of establishing county stations at representative points in the several distinct farming regions of the State in order to deal more adequately with local farming problems. There are eight of these local stations. Three of them, the Augusta, Charlotte, and Henry County stations, are supported by funds allocated for this purpose by the State Board of Agriculture from the fertilizer tax fund.

This report gives a review of the progress and results of experiments and invesitgations at these eight county stations for the period July 1, 1919, to June 30, 1927.

Appomattox County Station

This station is located near Appomattox Court House. The purpose of the station is to conduct experiments with dark fire-cured tobacco and other crops commonly grown on dark tobacco farms.

The soils of this section mostly belong to the Cecil series. The location of the experiments has changed from time to time due to the fact that the station owns no land in this county and has had to depend upon leasing land from different individuals for varying periods of time. The experiments in the past have been conducted on two types of soil, viz.: (1) Soils locally designated as "gray soils," which are classified as Cecil sandy loams by the Bureau of Soils, U. S. Department of Agriculture; and (2) soils known locally as "red soils," which are classified by the same authority as Cecil clays. The location of the station at the present, and since 1923, is on the Cecil clay soil type. The particular location is on land considered exceptionally well suited to dark fire-cured tobacco.

The results of the experiments at this station from 1911 to 1919, inclusive, are reported in our Bulletin 231, "Experiments With Dark Tobacco and Other Crops." Up to this time the experiments dealt chiefly with the effects of nitrogen, phosphoric acid, and potash, alone and in combination, on yield and quality of tobacco. The effect of lime on growth of tobacco and other crops of the section was also given considerable attention.

In 1919 the entire group of experiments was revised and new projects

written. These projects have been continued as outlined to the present time. The projects now under investigation are as follows:

1. A study of the effect of varying the proportions of nitrogen, phosphoric acid, and potash in a tobacco fertilizer on yield and quality of the crop.
2. A study of the sources of nitrogen and potash for tobacco fertilizers.
3. A study of rates of application and a comparison of "high-grade" and "low-grade" tobacco fertilizers.
4. Varieties of crops.
5. Pasture investigations.

A Study of the Effects of Varying the Proportions of Nitrogen, Phosphoric Acid, and Potash in a Tobacco Fertilizer on Yield and Quality of the Crop Produced.—The purpose of this experiment is to determine, if possible, the correct analysis for a tobacco fertilizer for general use on soils of this type.

The tobacco is grown in a three-year rotation of tobacco, wheat, and clover. Each plat is limed at the rate of 1,000 pounds of burnt lime or its equivalent to the acre before clover. In this experiment plat 1 is given an application of 100 pounds of ammonia, 100 pounds of phosphoric acid, and 100 pounds of potash to the acre before tobacco. In the succeeding plats the potash is reduced at the rate of 20 pounds per acre until on plat 6 no potash is applied. In the next five plats ammonia and potash are applied at the rate of 100 pounds to the acre and phosphoric acid is reduced in 20 pound units until no phosphoric acid is applied. In like manner, on the next five plats ammonia is reduced at the rate of 20 pounds to the acre until no ammonia is applied. Thus it is possible to study the effects of each plant food material used at varying rates when the other two are kept constant and used in sufficient quantities to supply the needs of the crop for them.

The results from the use of different amounts of potash indicate a regular increase in yield for each successive increase in potash. However, the average for eight years shows the highest value per acre is reached when 60 pounds of potash is applied to the acre and that the optimum amount is reached when 40 pounds is applied to the acre, because further increases are not sufficient to pay for the additional fertilizer.

In the different amounts of phosphoric acid there is a regular increase in crop value and yield up to 60 pounds of phosphoric acid per acre. Thereafter both yield and crop value recede.

The results from the use of different amounts of ammonia are conflicting. The yield per acre is increased for each successive increase in ammonia. The crop value per acre increases up to 40 pounds of ammonia but thereafter it is conflicting.

From these results it appears that the best combination of ammonia, phosphoric acid, and potash for these soils is 40 to 50 pounds of ammonia, 60 to 80

pounds of phosphoric acid, and 40 to 50 pounds of potash. However, this record cannot be considered as conclusive, as several adverse seasons, including a hail storm and a severe drought, have had a tendency to affect the results.

A STUDY OF SOURCES OF AMMONIA AND POTASH FOR TOBACCO FERTILIZERS.—The purpose of this experiment is to determine the relative results from the use of certain ammonia carriers alone and in combination and to compare muriate and sulphate of potash as to their effect on yield and quality of tobacco.

In this experiment nitrate of soda, sulphate of ammonia, dried blood, and a combination of the three are compared when the amounts of phosphoric acid and potash remain constant. In the comparison of muriate and sulphate of potash, ammonia and phosphoric acid remain constant.

In these tests dried blood, an organic nitrogen carrier, has given better results than either of the inorganic carriers tried. However, the plat which receives one-third of its nitrogen from an inorganic source and two-thirds from organic sources has given better results than any single nitrogen carrier. These results suggest that the nitrogen in a tobacco fertilizer should be derived from both organic and inorganic sources and that from one-third to one-half of it should come from inorganic sources.

In the comparison of muriate and sulphate of potash, the highest average value per acre was obtained from the muriate of potash plat; but the sulphate of potash plat gave slightly higher yields per acre. It appears from these results that quality of the tobacco (as determined by the buyer) is better where muriate of potash is used. However, the burning quality of the tobacco, as determined by burning tests, is better on the sulphate of potash plats. Preliminary tests indicate that when half of the potash is obtained from muriate and half from sulphate of potash, better results may be expected than when a single source of potash is used.

A COMPARISON OF "LIGHT" AND "HEAVY" APPLICATIONS OF 8-3-3 FERTILIZER AND A COMPARISON OF 8-3-3 AND 8-2-2 FERTILIZER WHEN USED AT THE SAME RATE.—The purpose of this experiment is to answer questions of considerable local importance as to the relative results of "high" and "low" grade fertilizers and of light and heavy applications of fertilizers. In these experiments an application of 1,000 pounds of an 8-3-3 fertilizer to the acre has given an average crop value of $30.00 more per acre than has an application of 500 pounds of an 8-3-3 fertilizer. In the comparison of 1,000 pounds of 8-3-3 fertilizer with 1,000 pounds of 8-2-2 fertilizer the 8-3-3 has given an increased crop value of $20.00 per acre.

VARIETIES OF CROPS.—The purpose of this experiment is to determine the best varieties of the different crops grown in the section. In these experiments the more important varieties of crops are planted in adjacent plats and yields and other characteristics are compared.

In the tobacco variety tests a local selection from Lizard Tail Orinoco,

known as Little Dick, has given an average acre value of $19.00 more than its nearest competitor which has been Lizard Tail Orinoco.

In the corn variety tests the large, one-eared types such as Boone County White, Johnson County White, Caseys Pure Bred, and Virginia White Dent have given the largest yields and there seems to be little choice between the varieties named. Leaming and Reids Yellow Dent are the outstanding yellow kinds, while Cockes Prolific has been the best ensilage variety as determined by the total yields of grain and stover per acre.

Of the wheat varieties, V. P. I. 131, V. P. I. 112, and Stoner have yielded practically the same and lead all other varieties tried.

Abruzzi has proved the best variety of rye for winter pasture and green manuring but is slightly behind Piedmont Winter in yield per acre.

Virginia Gray Winter is the leading winter oat tested. The Fulghum and Red Rust Proof seem to be the best spring varieties of oats for the section.

In the potato variety tests V. P. I. Green Mountain is outstanding. Irish Cobbler is the best yielding early variety, with Early Rose a close second.

Pasture Investigations

It is characteristic of the section known as Middle Virginia, and largely true of most of the State east of the Blue Ridge mountains, that the pasture lands, as a rule, are chiefly those which were formerly cultivated and have become unproductive by reason of erosion or soil exhaustion by continued cropping, and abandoned to such pasturage as they will afford, or else turned out as waste land. There are exceptions to this practice, but it is safe to say this is the general rule. Statistics tend to show that the increase in population of the United States is greater than the increase in the production of meat animals, and that the per capita supply of meat for food is falling off, suggesting either a greater demand and higher price for meat animals to stimulate production or a change from meat to vegetable diet. As far as Virginia is concerned, any substantial expansion of the livestock industry will necessarily have to be brought about by the utilization of the lands east of the mountains. These lands are not naturally as well adapted to the production of pasture grasses (that is, native grasses, such as bluegrass) as the mountain and valley sections. There is a question as to whether the production of livestock upon pastures can be made profitable on these east-of-the-mountain lands in competition with the better pasture lands of the State and the livestock sections of the United States. There is a question whether the Exension Division or our Experiment Station, without more definite information on the subject, would be warranted in advising and encouraging our east-of-the-mountain farmers to venture extensively into the livestock industry. There never has been any question as to the fact that good pastures can be made on these eastern lands by proper methods of management. The question is whether it will be profitable

in the production of livestock at prevailing prices for meat animals and dairy products.

In consideration of the foregoing, some pasture experiments were started on typical worn-out, old-field pasture lands of this section. These experiments are being conducted on the farm of J. R. Horsley, near Stapleton, Virginia. The information sought from these experiments is as follows:

1. The cultivated grasses best suited to the soils for pasturage for an all-seasons pasture, singly or in mixtures.
2. The cost of such pasture improvement.
3. A fair comparison of the amount of grazing afforded by such improved pastures and the unimproved old-field pastures.
4. The comparison of limed and unlimed lands in the production of pasture grasses.
5. The possibility, by selection of suitable pasture mixtures or pasture grasses, to lengthen the grazing season and shorten the feeding period during the winter months, and to what extent spring and fall grazing crops, such as rye, etc., could be used to this end.
6. The direct gains which might be made in livestock weight from rye grazing and the cost of such gains.
7. The practicability in connection with other farming operations, of rotations with rye as a grazing crop and soybeans as a hay or grain crop as a substitute for wheat as a money crop and as a partial substitute for corn as a grain crop, together with the resultant effect on the fertility of the land.

Perhaps the best comment that can be made upon the results of these experiments at this time is to answer, as far as possible, the seven questions raised above. As yet no conclusive results have been obtained, but indications are very favorable as to several of the questions.

In all of the experiments, both in small plats and on the field scale, with permanent pasture mixtures, the soils selected have been typical Cecil sand or Cecil sandy loam of the section, which types of soil largely predominate in this section. With the exception of the field used for the small plats of one-fifth acre (which has been cleared about forty years, was comparatively unimproved pasture land, but had not been eroded), the lots selected were worn-out, old-field pasture lands, four of which were badly eroded and abandoned as cultivated land doubtless largely for that reason. In the face of unusual drought through several successive years, the seeding of these fields to mixtures of tame grasses has resulted uniformly in from fair to excellent stands. In the face of heavy grazing through long periods of summer drought the stands have withstood the grazing and drought to an amazing degree, and every field at this time shows a fair sod of the grasses seeded, in which some of the grasses in the mixtures either failed of a stand at the time of seeding or have since disappeared, but a sufficient number of the grasses of the mixtures, of one sort or another, have persisted and still furnish a fair pasture sod.

It is noteworthy that these "made," cultivated-grass pastures are ready for use much earlier in the spring and furnish grazing much later in the fall, and are also much more palatable to the cattle than the broom sedge and other

native grasses. In 1926 but for the several fields of pasture included in these experiments, on account of the severe and protracted drought, from April 1 to November, it would have been impossible to carry the cattle through the summer without feeding. The pastures got a good start in the early part of the season while the rye grazing lasted, which helped materially in adding to the grazing for the season.

None of the experiments have been more expensive than the average farmer could afford on a field scale. The cost of two tons of lime, from four to five hundred pounds of 16 per cent. superphosphate, and the seed, which was about the same of the average hay grass mixture, was the sum of the money outlay. The preparation of the land was done mainly with the farm force at convenient seasons that would not interfere materially with the other farm operations. In the case of the steep and badly eroded fields, the gullies were plowed in to some extent, and a system of very simple drains or terraces was put in to prevent further erosion. In addition to the improvement in the pasturage it may be remarked that the erosion of the soil has been arrested, which is worthy of consideration.

A Test of Pasture Grasses.—This experiment was begun the fall of 1923 with a series of pasture grass seedings. In September the lot which was divided into plats of one-fifth acre each was seeded to various pasture mixtures, as shown by Table 26. On the plats where Japan clover is mentioned in the mixture, the seeding of Japan clover was deferred until the following spring. By an oversight, the bluegrass seed was not sent with the bill of seeds, and the blugrass was also seeded the following spring where it is indicated in the mixtures. The ground was exceedingly dry in the spring and neither the bluegrass nor the Japan clover made a good showing. The other grasses, except the plat seeded solely to orchard grass, germinated well and made a good showing the following summer. The lot was inclosed and it was not grazed excessively the summer after seeding. But, since that time it has been heavily grazed. The plat seeded to sweet clover with Herds grass did not give a stand of sweet clover, probably for lack of lime and inoculation. Each of the plats was treated with 400 pounds of 16 per cent. superphosphate to the acre, and two tons of lime, which was not applied until the following August. No other fertilizer or manure was applied until the spring of 1925, when about seven tons of manure to the acre was applied uniformly to all the plats. The sod still remains on all of the plats, the clovers having in most cases disappeared, except the Japan clover. The sheep fescue is noticeably persistent. The plat seeded to orchard grass, tall meadow oat grass, and Japan clover has furnished better winter grazing and probably the most grazing of any of the plats.

Table 26 shows a comparison of the results from the different seedings. It will be noted that four grasses and one clover have been very persistent. These are orchard grass, sheep fescue, tall oat grass, redtop, and Japan clover. Though white clover was not seeded in any of the mixtures it has come into all

TABLE 26.—A COMPARISON OF DIFFERENT GRASS MIXTURES.

Kind of Seed and Pounds Seeded per Acre	Date Seeded	Notes Taken June, 1924	Notes Taken June, 1925	Notes Taken May, 1926	Notes Taken May, 1927
Red clover, 8 lbs. Timothy, 10 lbs. Redtop, 5 lbs.	Sept. 10, 1923	Red clover and timothy thin. Redtop good	Timothy and clover very thin	Clover and timothy practically gone	Redtop good, other plants gone
Orchard grass, 14 lbs.	"	Thin stand but plants vigorous	Increasing	Orchard grass increasing. Some redtop	Orchard grass fair. Some redtop
Orchard grass, 14 lbs. Red clover, 8 lbs. Redtop, 5 lbs.	"	Red clover thin. Orchard grass and redtop good	Clover practically gone Others good	Clover gone	Orchard grass and redtop good
Orchard grass, 14 lbs. Perennial rye, 10 lbs. Alsike clover, 6 lbs. Bluegrass, 10 lbs.	Bluegrass April, 1924	Orchard grass good. Other plants thin	Orchard grass good. Other plants thin	Orchard grass good. Other plants thin	Orchard grass good. Bluegrass increasing
Orchard grass, 14 lbs. Alsike clover, 6 lbs. Bluegrass, 10 lbs.	"	Orchard grass good. Others thin	Alsike very thin. Bluegrass thin	No alsike. Bluegrass better	Mostly orchard. Bluegrass increasing
Orchard grass, 14 lbs. Sheep fescue, 5 lbs. Alsike clover, 6 lbs.	"	Alsike thin. Orchard grass and fescue good	Alsike thin. Orchard and fescue good	Alsike gone. Orchard and fescue good	Orchard grass and fescue good
Orchard grass, 14 lbs. Sheep fescue, 5 lbs. Japan clover, 10 lbs.	Japan clover April, 1924	Orchard grass and fescue good. Japan clover thin	Orchard grass and fescue good. Japan better	Orchard grass and fescue good. Japan clover increasing	All good
Orchard grass, 14 lbs. Tall oat grass, 11 lbs. Redtop, 5 lbs. Japan clover, 10 lbs.	"	Japan clover thin. Other plants good	Japan clover thin. Other plants good	All good	All good
Sweet clover, 10 lbs. Japan clover, 10 lbs. Redtop, 5 lbs.	"	Sweet clover very thin. Japan thin	No sweet clover. Japan thin	Japan increasing. Redtop good	Redtop and Japan clover good
Orchard grass, 14 lbs. Tall oat, 11 lbs. Red clover, 6 lbs. Redtop, 3 lbs.	"	Red clover thin. Other plants good	Red clover thin. Others good	Red clover gone. Other plants good	Red clover gone. Other plants good

NOTE: April 15,1927. There is some white clover scattered over the entire area and a sprinkling of low hop clover. Bluegrass is slowly increasing where seeded and it is spreading to adjoining plats.

of the plats. It is likely that a grazing mixture for soils of this type should be made up chiefly of these plants. Bluegrass will doubtless occupy an important place as the soils are improved but probably should not be seeded except on the good lands of the section.

A COMPARISON OF PASTURAGE ON LIMED AND UNLIMED LANDS.—For this experiment an area of approximately ten acres was cut out of a pasture. One-half of the field had been limed at the rate of 2 tons of ground limestone to the acre three years previously and seeded to a mixture of timothy, redtop and clover. The other part of the field was unimproved and had grown up in broom sedge and other naitve grasses. At the time of reseeding the pasturage was poor over the entire area though some redtop persisted on the limed part of the land.

The whole field was plowed and seeded to a mixture of 14 pounds of orchard grass, 11 pounds of tall oat grass, 8 pounds of alsike clover, 4 pounds of white clover, and 10 pounds of Japan clover in April 1923. The whole area

received an application of 300 pounds of 16 per cent. superphosphate at the time of seeding and the limed area received an additional application of one ton of ground limestone to the acre. A splendid stand was secured on the whole field. The field was inclosed and the grazing was limited to a few weeks in late summer and early fall for the first season. Since that time it has been subjected to unlimited grazing a large herd of cattle having free access to it at all times except during the winter months.

The limed part of the field was in conspicuous contrast to the unlimed part from the first. Though no measure of yields could be made it is conservatively estimated that the limed half has afforded more than twice as much feed to the cattle throughout the period. At the present time the sod is still good on the entire field though it is much better on the limed part.

Alsike clover disappeared after the second year. However, lespedeza and white clover have increased on the limd area. At the present writing there is little but orchard grass, red top, and lespedeza on the unlimed area, while on the limed area both white clover and tall oat grass also still persist.

To Test the Practicability of Seeding Badly Eroded Waste Land to Pasture Plants.—For this experiment two steep hillsides were chosen, one facing the northeast and the other the southeast. These hillsides had not been plowed for many years and were sparsely covered with dewberry vines and broom sedge. The land was very badly eroded, the red subsoil being exposed in many places and gullies two to four feet deep were abundant. The land on the northeast slope was plowed in January, 1925. All gullies were plowed in as well as possible and the washing was checked by well-graded terraces or hillside water furrows. The field was limed at the rate of 2 tons of lime to the acre and fertilized with 500 pounds of superphosphate to the acre. In April, 1925, it was seeded to a mixture of 10 pounds orchard grass, 10 pounds perennial rye grass, 5 pounds redtop, 5 pounds sheep fescue, 10 pounds sweet clover, and 10 pounds Japan clover to the acre.

The sweet clover failed completely but the other plants made a good stand. This field was grazed lightly during the summer of 1926 but was subjected to unlimited grazing in 1927. Though the season was very dry the field grazed well. It is esitmated that it furnished at least six times as much herbage as the southeast slope which had not been plowed. Erosion has been completely stopped and the old gullies are grassed over. This field demonstrated the feasibility of preventing erosion by seeding waste lands in Middle Virginia to useful species of pasture plants and at the same time producing summer feed for livestock.

In August, 1926, the southeast hillside was plowed, terraced, limed, fertilized, and seeded to the same mixture that has done so well on the northeast slope. At the present writing it is looking well. The mixture used was in the way of an experiment. However, on the recently seeded field the sweet clover as well as all of the other plants are looking well at the present time.

In view of this and other experiments, probably a more practicable mixture for conditions such as this would be 10 pounds orchard grass, 10 pounds sheep fescue, 5 pounds redtop, 3 pounds white Dutch clover, and 8 to 10 pounds of lespedeza. As the land improves sweet clover may be seeded on the pasture in late winter. However, we have yet to prove that sweet clover is a good pasture plant for the thin lands of this section. Sheep fescue seems to be particularly valuable for thin and eroded spots while orchard grass is fine for the more productive parts of the fields.

To Determine the Practicability of Growing Abruzzi Rye in a Good Feed Producing Rotation for the Purpose of Giving Early Spring Pasturage.—For this purpose a rotation was established: first year, corn followed by Abruzzi rye to be grazed the following spring; second year, soybeans for seed or hay; third year, small grain; fourth year, clover. Two very dry years (1925 and 1926) have caused very unfavorable results with soybeans in this rotation. However, it is believed that in normal seasons this rotation will furnish considerable feed. It is planned to replace half of the acreage in corn by soybeans as it is believed that this crop will furnish as much feed to the stock as corn at a lower cost for production and at the same time lessen erosion which always takes place when these hill lands are planted to corn. The results obtained from grazing Abruzzi rye were very surprising and gratifying.

In 1925 a 25-acre field of Abruzzi rye was grazed with 50 head of cattle for 40 days. The cattle were run into the field for a few hours each day for the first week so that they would become accustomed to the green feed and fill up before weighing. They were then weighed and turned into the field. The gain made on the rye was 4,440 pounds, or 177.6 pounds to the acre.

In 1926, 48 head of cattle were turned on a field of 20 acres of Abruzzi rye on March 29 and taken off on April 30. The total gain in weight for the period was 3,030 pounds, or 151.5 pounds to the acre. These cattle were thin both years when turned in but they gained rapidly. Since the cattle were allowed to fill up on the rye before the first weighing, the gains represent real gain and not merely fill. Since feed was short both years, it would have been necessary to buy roughage to keep the cattle alive until grass was available if it had not been for the rye.

To Determine the Practicability of Clearing Cut-over Land for the Purpose of Pasture Making with Angora Goats.—For this purpose an area of about 8 acres of land was burnt over after the trees were in full leaf in May. This burning killed practically everything on the land. The field was then fenced and a herd of goats was turned in. The goats have kept all sprouts cleared out and it is believed that in another year most of the brush will be down and the land in good condition for seeding grass.

James City County Station

This station is located near Williamsburg on a Norfolk fine sandy loam soil. Experiments were begun in this locality in 1912. The earlier work of the

experiment station was chiefly investigations with alfalfa. The results of these experiments may be found in our Bulletin 247. The findings in reference to this crop may be briefly stated as follows:

1. Land for alfalfa should contain organic matter in sufficient quantities to afford a suitable medium for bacterial development.
2. The soil should be finely pulverized and leveled so seed will germinate uniformly and the crop can be harvested with a minimum of effort.
3. Lime should be applied because the crop uses calcium in relatively large quantities and because lime corrects acidity and favors bacterial development.
4. Phosphorus and potassium are both deficient in the soils of this area and must be supplied in liberal quantities in order to grow economical crops.
5. Farmyard manure is an excellent source of organic matter, nitrogen, and potassium. Therefore, farmyard manure supplemented by superphosphates makes an ideal alfalfa fertilizer.
6. The seed or soil should always be inoculated because uninoculated legumes use more soil nitrogen than non-legumes and uninoculated alfalfa usually fails to produce paying crops.
7. Sow 20 to 25 pounds of American-grown alfalfa seed to the acre in late summer.
8. Grimm and other so-called hardy varieties of alfalfa have no advantage over common American-grown alfalfa for this section.
9. Cultivation has neither lengthened the life of the crop nor decreased the weeds in the alfalfa fields of this section.
10. Alfalfa should not be cut until the shoots which are to make the next crop have made a good start.

In 1924 the work of the station was terminated at the old location and a complete line of new projects was begun on a similar soil type on a nearby farm. At this new location more attention is being given to forage crops other than alfalfa, and other field crops common to the section. In 1924, at the request of farmers of that section, field plats were located near Montross in Westmoreland County to investigate certain difficulties which were being met in the production of wheat and red clover in that section. This work was under the supervision of the superintendent of the James City County station and was continued without interruption until the fall of 1927 when it was terminated.

Williamsburg Projects

Rates of Liming.—This experiment is a part of an investigation which is being conducted at two other county stations to determine the proper rate of liming for different crops on different soil types of the State. These tests are arranged in three rotations as follows: (1) Corn, wheat, and alfalfa; (2) potatoes, oats, and red clover; (3) soybeans, rye, and sweet clover. Ground limestone is applied at rates varying from none to 3,000 pounds to the acre. The plats are so arranged that each crop is planted each year on plats which have

received lime at the varying rates. On each plat in a series each succeeding plat receives 600 pounds to the acre more than did the preceding plat. This experiment must continue a number of years longer before definite conclusions can be drawn. The indications to date are as follows:

1. Yields of potatoes are not markedly increased by the use of lime.
2. Six hundred pounds of ground limestone to the acre profitably increased the yields of soybeans. Applications of greater amounts did not pay.
3. The yield of corn was increased six bushels to the acre by the application of 600 pounds of limestone to the acre. Applications of greater amounts did not show profitable returns.
4. There were slight increases from the application of 600 pounds of limestone to the acre to wheat, but hardly enough to pay the expense of the application.
5. Oats have not showed profitable returns from the use of lime.
6. The yield of rye is profitably increased by limestone applications up to 600 pounds to the acre. Beyond this increased applications do not pay.
7. Sweet clover fails completely without lime. The growth increases for each increase in lime to the limit used in the experiment. The most economical application seems to be 2,400 pounds of ground limestone to the acre.
8. Red clover profitably responds to lime applications up to 2,000 pounds of ground limestone to the acre.
9. Alfalfa profitably responds to lime applications up to 2,000 pounds of ground limestone to the acre.

Alfalfa Fertilizer Experiments.—The chief object of these experiments is:

(1) To find out the proper proportions of nitrogen, phosphoric acid, and potash to use in an alfalfa fertilizer;
(2) to find the most satisfactory rate of application; and
(3) to determine whether stands of alflafa may be maintained by top dressing with fertilizer.

The results now available indicate the following points:

1. When alfalfa is seeded on land well supplied with organic matter the chief benefit of nitrogen is to give the crop a quick start and thus enable it to better withstand winter conditions.
2. Phosphoric acid and potash should be applied in the proportion of two parts of phosphoric acid to one part of potash.
3. Under the conditions of the experiment, 100 pounds of phosphoric acid and 50 pounds of potash to the acre give the most profitable returns. The experiment has not been under way long enough to determine the value of fertilizer top dressings.

Soybean Studies.—These experiments include:

(1) Cultural studies of soybeans;
(2) shattering studies;
(3) varieties for grain and hay; and
(4) a comparison of palatability of different varieties for hog pasture.

The cultural experiments show that there is only a slight difference in the yield of soybeans when sown broadcast and when seeded in narrow rows and

cultivated. For this reason it seems more economical to sow beans broadcast with a grain drill unless labor is very cheap and seed very high.

The shattering studies show that the George Washington and Pine Dell varieties hold their seed longer without shattering than any other varieties tested. Hollybrook, Austin, Laredo, Mammoth Brown, and Tokyo also hold their seed very well and are, therefore, well suited to hog pastures.

Laredo, Pine Dell, George Washington, and Chiquita are among the highest yielding hay varieties. The yield of grain from the different varieties fluctuates greatly from year to year. However, Virginia, Hollybrook, Haberlandt, Lexington, and Laredo have been consistently good grain yielders.

The palatability tests on Haberlandt, Morse, Virginia, and Wilson show that hogs have a decided preference for Haberlandt and Morse soybeans, both of which are light colored beans.

Alfalfa and Clover Tests.—The purpose of these tests is to compare varieties and strains of alfalfa and red clover from different sources. Kansas and Utah grown common alfalfa have consistently given better results than other varieties from different sources. The Virginia and Tennessee grown strains of red clover have been outstandingly better than other kinds tried. European strains of red clover have given uniformly unsatisfactory results.

Pasture Plant Investigations.—The purpose of these tests is to find satisfactory pasture plants for the section. The results of this experiment show that orchard grass, redtop, tall oat grass, sheep fescue, Canada bluegrass, white clover, and lespedeza are the most promising permanent pasture plants yet tried for the section. The Kobe variety of lespedeza seems particularly well adapted for summer grazing as it grows larger than other varieties of this species.

Summer and Winter Cover Crops for Soil Improvement.—The purpose of this study is to compare certain legumes for cover crops. This experiment has not been running long enough to give conclusive results. However, certain newly introduced legumes show decided promise as soil improving crops. They are Crotalaria, Dalea clover, and Austrian winter pea.

Blackeye Pea Selection Work.—The purpose of this project was to select a strain of peas suitable for the canning trade. A strain has been segregated which meets the approval of the canners. This is now in the hands of a large grower and is being multiplied rapidly.

Montross Projects

Fertilizer Experiment on Corn, Wheat, and Clover With and Without Lime.—To determine a profitable fertilizer practice for the corn, wheat, and clover rotations of the section. It was soon determined that lime was the limiting factor in clover production of the section and that where phosphoric acid and potash were applied in the rotation and lime used, satisfactory and profitable crops of clover could be produced. Where good clover sods were plowed under no nitrogen was needed for satisfactory production of corn and

wheat, but even where lime and organic matter were supplied, both phosphoric acid and potash were necessary for economic production of these crops.

The experiments indicate that where legumes are grown regularly in the rotation, phosphoric acid and potash should be applied in the ratio of three parts of phosphoric acid to one of potash and that thirty pounds of phosphoric acid and ten pounds of potash applied to corn and wheat in the rotation is an economical amount to use.

ALFALFA FERTILIZER EXPERIMENT.—To determine the best fertilizer for alfalfa in the section. Lime is essential to alfalfa and should be applied at the rate of one ton of ground limestone or its equivalent to the acre before seeding. Approximately 100 pounds of phosphoric acid and 50 pounds of potash to the acre are necessary for success with the crop when the land is well supplied with organic matter. When organic matter is deficient in the soil, nitrogen should be applied at the rate of 50 pounds to the acre in addition to the phosphoric acid and potash.

Caroline County Station

The Caroline County Station is located near Bowling Green on a Norfolk sandy loam soil. It was established in 1908 for the purpose of conducting experiments with sun-cured tobacco and crops commonly grown on tobacco farms of the section. Until 1920 the experiments conducted were of the type already described for the other tobacco stations. The results of these experiments have been reported in our Bulletin 242.

In 1920 a cooperative arrangement was entered into with the Bureau of Plant Industry, Office of Tobacco Investigations, United States Department of Agriculture, and the station was moved to a new location in order to obtain sufficient land for the new experiments. Since that time the major part of the work of the station has been on the cooperative experiment. However, some other projects of local importance have been conducted throughout the period.

PLANT NUTRITION AND CROP RELATIONS INVESTIGATIONS.—The purpose of this investigation is to study the effects of crops upon other crops which may succeed them with and without fertilizer. The ultimate object is to find the fundamental principles underlying rotation building.

There are three parts to this project. In part one, tobacco, corn, and potatoes are arranged in a cropping scheme which allows each crop to follow itself and each of the other crops each year. This allows a study of the relative effect of each of these crops on the subsequent growth of the others.

In part two, corn, tobacco, potatoes, wheat, oats, and rye are arranged so that each of the cultivated crops is followed by each of the small grain crops and each of the small grain crops is followed by each of the cultivated crops each year. This is the second step in rotation building and allows the relative effects of small grains and cultivated crops upon the growth of each other.

Part three is similar to part two except that each year each small grain crop is followed by cowpeas, soybeans, vetch, crimson clover, and mixed grasses. These crops are turned under the following year before the cultivated crops are planted, giving an opportunity to study the effects of legumes and mixed grasses in a rotation.

Rotation experiments are necessarily slow and it is difficult to draw conclusions until the experiments have been continued for a long time. However, the experiments have been successfully carried through each year and many data have been obtained from the 460 plats involved in the investigations. Some of the facts that seem apparent from the results of the experiment to date are:

1. Corn shows more depressing effects upon crops following it than any of the other crops grown.
2. Potatoes depress growth of seeding crops less than either corn or tobacco.
3. The small grains used do not seem to differ in their effects on the crops whcih follow them.
4. Vetch is the most efficient legume used in keeping up soil nitrogen.
5. Cowpeas and soybeans do not differ materially in their effects on succeeding crops when both are properly inoclulated.
6. Where mixed grasses have been seeded after small grains and turned under for cultivated crops the following spring, yields are far behind plats which had legumes turned under and very little better than no cover crop.
7. A deficiency of potash in the soil has caused a quick depreciation in quality in tobacco which is cumulative as the experiments progress.
8. Deficiency in potash for corn is indicated by blades turning yellow and a weak root system, causing stalks to fall over before maturity.
9. A deficiency of phosphorus is first evidenced by slow maturity of crops followed by rapidly diminishing yield and quality.
10. Profitable yields have been maintained where liberal applications of complete fertilizers were used, even under continuous cropping to cultivated crops.

Fertilizer Experiment.—This experiment was started in 1926 for the purpose of determining the best sources of nitrogen and potash for tobacco. Fertilizers with widely varying analyses are also being studied in their effect upon yield and quality. This experiment is now in progress.

Forage Investigations.—To study the comparative value of certain forage plants for the section. Vetch seems to be the most satisfactory annual winter legume for late seeding while crimson clover is well suited for July and August seedings. Austrian Winter peas, a newly introduced legume, has given good results the two years it has been tested and bids fair to be a valuable crop for winter cover and early hay crops. Cowpeas and soybeans have been the best summer annual legumes tested. Soybeans have been superior to cowpeas in yield of both hay and seed.

Selection Work With Tobacco.—To improve the yield and quality of tobacco by individual plant selection. A strain of tobacco has been established

which has decided resistance to leaf spot diseases. This strain quickly became popular and is now widely grown in the section under the name of Green's Wildfire Resistant.

VARIETY TESTS.—The purpose of these tests is to compare varieties of the crops commonly grown in the section. Green's Wildfire Resistant, a selection from Little Orinoco, has proved the most valuable tobacco variety for the section. The highest yielding white variety of corn for the period of the test has been Boone County White, and Leaming has been the highest yielding yellow variety. The wheat variety tests show little significant difference in yield for the period. Abruzzi rye has been outstandingly better for both grain and forage than any other variety tested. V. P. I. No. 1 has led in yield in the winter oat tests and Fulghum has led in the spring oat tests.

Pittsylvania County Station

The Pittsylvania County station is located near Chatham on soil classified by the Bureau of Soils of the United States Department of Agriculture as Cecil fine sandy loam. The purpose of this station is to conduct experiments with bright flue-cured tobacco and crops commonly grown on bright tobacco farms. The soil on which these experiments is conducted is not considered the best type of bright tobacco soil but it constitutes a much larger proportion of the soil on which bright tobacco is grown in the State than do the better types of bright tobacco soils. The station was established in 1907, and in 1922 it was decided advisable to discontinue a number of the older experiments and to begin a number of new projects at a new location. The results of these older experiments are reported in our Bulletins 198 and 233. In order to have this report cover the period from 1919 to the present it will be necessary to discuss both the old projects which have been discontinued, and the new projects which are now under investigation.

OLD PROJECTS

FERTILIZER EXPERIMENTS WITH TOBACCO.—The purpose of this experiment was to study the effect of various fertilizers on tobacco with and without lime. One of the most striking features of these experiments is the fact that no fertilizer consisting of a single element gave satisfactory results. Nor was the combination of any two of the elements sufficient to give profitable returns. Of the single elements, phosphorus gave the highest acre value. A complete fertilizer containing ammonia, phosphoric acid, and potash was necessary for profit. It was also found that relatively an amount of plant food in excess of what a normal crop uses was necessary for best returns. This is evidenced by the fact that increasing the amount of fertilizer used from 700 pounds to 1,400 pounds increased the acre value of the crop $95.00.

Attempts to improve on the standard bright tobacco fertilizer analysis, which is 8-3-3, has not met with success. In this test where 1,000 pounds of

fertilizer were used to the acre, a reduction of either of the elements below the standard analysis caused a reduction in proceeds. When either nitrogen or potash was increased the proceeds per acre were slightly increased but not sufficiently for paying results. An increase of phosphoric acid from 8 per cent. to 11 per cent. caused a decrease in selling price per acre.

Effects of Lime on Bright Tobacco and Crops Grown in Rotation With It.—The purpose of this project was to study the effects of lime on yield and quality of tobacco and crops which are commonly grown in rotation with it. In practically every case where lime was used in a bright tobacco rotation over a long period of time, both quantity and quality of the crop was reduced. Since in these experiments lime was used at the rate of 2,000 pounds of calcium oxide or its equivalent every fifth year, it is probable that too much lime was used. More recent experiments indicate that light applications (not more than 1,000 pounds every fifth year) of dolomitic limestone is efficient for avoiding sand drown and will not injure the crop. The crops of wheat, corn, and hay grown in rotations with the tobacco were practically twice as large on the limed than on the unlimed plats. Also the efficiency of the fertilizers was greater on the limed plats. This suggests that the tobacco farmer should have two rotations on his farm; one for bright tobacco, to which lime is not applied except as a remedy for sand drown; and the other for grain and forage crops to which lime is applied in sufficient quantities to insure good clover crops.

New Projects

As already indicated, the experiment station was moved to a new location in 1923 and a number of new projects were begun. Certain uncompleted projects were continued on the new location also. The following projects were undertaken on the new location and have continued to the present time:

1. Rate and analysis test of fertilizers for tobacco;
2. Sources of plant food elements for tobacco;
3. Potash, sulphur, and chlorine tests on tobacco;
4. Cultural tests with tobacco;
5. Fertilizer and lime tests on a grain and grass rotation;
6. Variety tests.

Rate and Analysis of Fertilizers for Tobacco.—To determine the best analysis for a bright tobacco fertilizer and to test different rates of application of a standard tobacco fertilizer. As in the old experiments, it has not been found profitable on the average to apply more than 80 pounds of phosphoric acid, 30 pounds of potash, and 30 pounds of ammonia to the acre to bright tobacco. The standard 8-3-3 fertilizer has been consistently better than 8-2-2 fertilizer, which is used by many farmers in the section; and it has been more profitable than other combinations tested. In the rates of application tests, 1,200 pounds of 8-3-3 fertilizer to the acre has proved to be the most profitable application.

SOURCES OF PLANT FOOD ELEMENTS FOR TOBACCO.—To determine the best sources of nitrogen, phosphoric acid, and potassium for tobacco fertilizers. The sources of nitrogen feature of this experiment has been continued for eight years. The results of the experiment have varied considerably from year to year. As a whole, the readily available inorganic nitrogen carriers have been more efficient in dry and normal years while the organic carriers have been more efficient in wet years. As an average for the entire period, the greatest crop value has been secured where three-fourths of the nitrogen was obtained from readily available inorganic sources and one-fourth from easily decomposable organic sources. The sources of phosphoric acid and potash feature of the project was started in 1923. The results have been quite consistent from the beginning. Superphosphate has proved to be the most efficient source of phosphoric acid. In the potash tests, muriate of potash and other potash salts carrying relatively high proportions of chlorine have given better average yields and acre value than sulphate of potash. However, burning tests show that tobacco grown with sulphate of potash has a higher burning quality than that grown with the salts carrying chlorine.

POTASSIUM, SULPHUR, AND CHLORINE TESTS ON TOBACCO.—This is a part of a cooperative test being carried on with the Office of Tobacco Investigations, United States Department of Agriculture, and the North Carolina Agricultural Experiment Station. The purpose of this experiment is to study the factors influencing burning quality in tobacco, with particular reference to the elements mentioned. This experiment was begun in 1926. The results to date do not justify conclusions.

CULTURAL TESTS WITH TOBACCO.—This project includes:

(1) Rotation experiments;
(2) Methods of applying fertilizer;
(3) "High-grade" compared with "low-grade" fertilizers; and
(4) Comparisons of cutting tobacco with pulling tobacco leaves when plants are topped at different heights.

In the rotation tests an attempt is made to include legumes in rotations with tobacco for the purpose of furnishing a part of the nitrogen. To date such rotations have not been found practicable. The best rotations tried have been short rotations which do not include legumes, such as tobacco, wheat, and rye as a green manure crop. The results from methods of applying fertilizers have not been consistent, as an average for the four years of the best results have been obtained from applying all of the fertilizer in the row before planting and mixing it thoroughly with the soil. In the comparison of "high grade" and "low grade" fertilizers, highly concentrated fertilizers, such as 16-6-6, have given practically the same results as less concentrated fertilizers when the same amount of plant food is used to the acre. In the comparison of cutting tobacco and pulling leaves it has been found that topping plants at 16 to 20 leaves and pulling the leaves as they ripen has been more profitable than cutting and topping in the usual way.

Fertilizer and Lime Tests on a Grain and Grass Rotation.—The purpose of this experiment is to work out a practicable system of fertilizing and liming the grain and grass rotations on bright tobacco farms. These experiments show that it is very difficult to grow profitable crops of grain and grass on soils of this type when no lime is used and that profitable grain and grass crops may be grown when lime is applied in a rotation containing legumes. Phosphorus gives the best results of any fertilizer treatment tried on grain after good legume crops have been obtained. However, on the thinner lands of the section, it is profitable to apply both nitrogen and potash, in addition to phosphorus, for grain and grass crops, until good crops of legumes have been obtained.

Variety Tests.—To compare the most commonly grown varieties of crops for the section. Warne, and Gold Leaf, which is a selection from Warne, have given the highest acre value in the tobacco varieties tested. There has been no striking difference in wheat varieties as yields from all varieties have been low. In the corn variety tests there is little difference in the yield of any of the large one-eared types, such as Boone County White, Virginia White Dent, and Leaming. This group seems best suited to the section.

Nansemond County Station

This station is located near Holland on a Norfolk sandy loam soil. The primary purpose of the station is to conduct experiments with cotton and peanuts and the crops commonly grown in rotation with them. The station was established in 1914 and in the beginning the most important experiments were fertilizer and lime tests. The results of these experiments are reported in our Bulletitn 229 which was published in 1922. New experiments were started in 1922 as indicated by the following project discussions.

Rates of Liming.—To determine the most profitable rate of applying lime to corn, peanuts, soybeans, cotton, and potatoes. An acre of land is divided into five equal subdivisions one way and ten equal subdivisions the other way. The ten subdivisions are limed with ground limestone at varying rates beginning with no limestone on Plat 1 and 600 pounds on Plat 2, then increased by 300 pounds to the acre on each succeeding plat until 3,000 pounds is reached on Plat 10. The five subdivisions running the other way across the field are planted to corn, peanuts, soybeans, cotton, and potatoes, respectively, in the spring, and crimson clover, vetch, rye, oats, and wheat in the fall. This gives 1/50 acre plats for each crop limed at each of the different rates. This experiment has already shown that the rates of liming usually advocated for the crops of the section are entirely too large and that actually better yields may be obtained from smaller applications. The indications from the experiments to date are as follows:

1. Corn shows no response to the use of lime.
2. Cotton shows very slight increases for the use of lime, but where crimson clover is used in cotton rotations, the crimson clover is better where 600 pounds of ground limestone is

applied to the acre than where none is applied and this is profitably reflected in increased cotton yields.
3. Peanuts, soybeans, and potatoes give profitable returns for the use of lime up to 1,200 pounds of ground limestone to the acre, but thereafter there is no benefit from increased applications.
4. Vetch, rye, wheat, and oats show no response to lime applications.
5. Rotations including the crops used in the experiment should be limed at the rate of 1,000 to 1,200 pounds of ground limestone to the acre once in a four-year rotation, and more lime than this is not likely to give paying results.

A Comparison of Different Sources of Phosphoric Acid With and Without Lime.—To compare the value of superphosphate with other sources of phosphoric acid when calcium sulphate is added to the other materials in quantities equal to that in superphosphate. These experiments indicate that there is no need for sulphur in fertilizers for this section. The results seem also to indicate that superphosphate is the best source of phosphoric acid for the section. The yields of crops from this source of phosphoric acid are slightly better and all crops start quicker and give a better early growth where this source of phosphorus is used. There has been no noticeable difference in the comparative results of the different fertilizers with and without lime. However, there is a marked increase in the growth of cover crops on the limed plats which is reflected in the yields of the succeeding crops. Plats which have received gypsum and no lime have fallen off markedly in yield, indicating a rapid increase in soil acidity.

Fertilizer Application to Corn and Cotton.—To determine the value of nitrogen derived from different sources and to determine the best method of applying fertilizer to the crop. This experiment is being conducted in cooperation with several experiment stations in the cotton states. It was started in 1926 and therefore has not been running long enough to show conclusive results. To date nitrate of soda has been the most efficient source of nitrogen and all nitrate of soda has given practically as good results as where varying amounts of the nitrogen were obtained from organic sources. The best results from cotton have been obtained where all of the fertilizer used was applied before planting. In the case of corn, best results have been obtained where the phosphoric acid and potash were applied before planting and nitrogen was given as side dressings later in the season.

Tests With Concentrated Fertilizers on Cotton.—To compare high analysis fertilizers with ordinary commercial mixtures carrying the same total amounts of plant food. This experiment is being conducted in cooperation with the Bureau of Soils of the United States Department of Agriculture. It was started in 1927 and, therefore, only one year's results are available. These results indicate that high analysis fertilizers carrying as high as 64 units of plant food to the ton may be safely used on cotton, provided the applications are made a week or more prior to planting and the fertilizers are well mixed

with the soil. Applications of high analysis fertilizers at the time of planting and in direct contact with the seed have reduced stands and retarded early growth.

Cotton and Peanut Selections.—Many individual plant selections have been made with peanuts and cotton, some of which have proved very well adapted to the section. A selection from Trice cotton has proved its superiority through several years and is now rapidly increasing in popularity. In 1926 50 bushels of seed from this strain were produced on the experiment station and distributed to nearby farmers. In 1927 one farmer sold 700 bushels of seed from this strain. A superior strain of Jumbo peanuts has also been segregated and this is now being grown on increase plats for distribution next season.

Variety Tests.—The variety tests in this locality have been of very great value. This is evidenced by the fact that when the station was established, no Trice cotton was grown in the section. As a result of our tests, it was proved that Trice cotton was superior to other varieties for the section. At the present time Trice cotton is being grown in the section almost to the exclusion of other varieties. The experiment station has tested many varieties of soybeans as to their adaptability to hog feeding, which is one of the most important agricultural enterprises of the section. It has been determined that Ito San, Haberlandt, Hollybrook, and Mammoth Brown soybeans make an ideal succession of varieties for furnishing feed for hogs. Cowpeas have proved to be inferior to soybeans for both grain and forage and are not advocated for general planting. Brabham, and Iron have been most resistant to cowpea blight which is the chief enemy to the crop in this section. The large one-eared varieties of corn have not proved to be well suited to the section. They are among the best yielding varieties but, due to the damp climate, they are damaged in the shock after harvest. The semi-flint varieties, such as Blounts Prolific, Batts Prolific, and Cockes Prolific seem best suited for general use in the area.

Augusta County Station

The Augusta County station is located near Fishersville on a Dekalb soil. This soil type prevails over a large area in the Valley section of the State. Compared with the limestone soils of this area, it is low in productivity and suffers more in dry weather on account of the fact that it is usually low in organic matter and the capillary movement of water is interfered with on account of the shaly nature of the subsoil. The experiment station was moved to this location in 1921. The first two years on the new location were given over chiefly to preliminary tests which were made for the purpose of testing the uniformity of the land. In 1923 projects were begun which have been continued to date.

Rates of Liming Experiment.—This is the most extensive experiment being conducted at this location. Its purpose is to determine the best rate of applying lime to the crops of the section. The crops are grown in three rotations of three years each as follows:

(1) Wheat, sweet clover, and corn;
(2) Barley, red clover, and potatoes; and
(3) Rye, alsike clover, and soybeans.

Each crop area is divided into subplats which are limed at different rates. Beginning with no lime, each succeeding plat receives 600 pounds of ground limestone to the acre more than the preceding plat until the maximum of 4,800 pounds of ground limestone to the acre is reached. Thus each crop grown receives lime at all of the rates used. The lime applications are to be repeated every sixth year. There appears to be a marked difference in the response of the different crops to the lime treatment. At the present time the experiments show that:

1. Corn yields are little affected by the use of lime. There is a difference of only four bushels of corn to the acre on limed and unlimed plats and the maximum increase is reached when ground limestone is applied at the rate of 1,200 pounds to the acre.
2. Barley is increased five bushels to the acre by the use of lime and the maximum increase is reached when lime is applied at the rate of 1,200 pounds to the acre.
3. Wheat shows a two-bushel to the acre increase for the use of lime and the maximum increase is reached when lime is applied at the rate of 1,800 pounds of ground limestone to the acre.
4. Rye is increased slightly over one bushel to the acre by the use of lime and the maximum increase is reached where 1,200 pounds of ground limestone is applied to the acre.
5. The yield of red clover is increased approximately one ton to the acre when 1,800 pounds of ground limestone is applied to the acre. When this point is reached there are no further increases for the use of lime.
6. Sweet clover responds to lime treatment more than any other crop in the experiment. Where no lime is applied the crop is a complete failure. The crop yields increase with each successive increase of lime up to 3,000 pounds of ground limestone to the acre. At this point the average yield is 1.54 tons of hay to the acre. Additional amounts of lime do not further increase yields.
7. Soybeans are not markedly affected by the use of lime, but there are slight increases up to 1,200 pounds of ground limestone to the acre.
8. The maximum yield of alsike clover is reached with the application of 1,800 pounds of ground limestone to the acre.
9. Potato yields show no significant response to the use of lime.

Fertilizer Experiment With and Without Lime.—The purpose of this experiment is to determine the response of corn, wheat, and clover to various fertilizer treatments with special reference to phosphate carriers. The effects of lime in this experiment have been very marked, probably due to the fact that no clover can be grown on the unlimed plats and the beneficial effects of clover

are reflected in the corn and wheat yields. The fertilizer results have been conflicting; however, there is an indication that:

1. Superphosphate is the best source of phosphorus for such soils when lime is used, but basic slag is more efficient when no lime is used.
2. Triple applications of superphosphate every third year are quite as efficient as single applications every year.
3. Potash increases crop yields, but is more necessary on unlimed than on limed plats.
4. Sulphur may be a limiting factor in crop yields on these soils.

SOURCE OF ORIGIN OF CLOVER AND ALFALFA SEED.—To compare results of clover and alfalfa seed grown in different crop-producing sections. These tests prove that American grown clover seed is superior to imported clover seed. Virginia and Maryland grown seed have proved superior to seed grown in other sections of the United States. The Grimm variety of alfalfa grown in North Dakota has withstood winter killing and given better yields than other strains.

A COMPARISON OF SULPHATE OF AMMONIA AND NITRATE OF SODA FOR TOP DRESSING CORN AND WHEAT.—When small amounts (up to 16 pounds of nitrogen) have been used to the acre the sulphate of ammonia has given slightly increased yields over nitrate of soda, but where heavier applications were used the nitrate of soda gave best yields. This experiment is carried on in a rotation of corn, wheat, and clover. Better stands of clover have been obtained where nitrate of soda was used than on the ammonium sulphate treated plats.

LEGUME EXPERIMENT.—To compare the efficiency of certain legumes and non-legumes as cover crops to be sown in corn at the last cultivation. Striking results are obtained from the use of legumes as winter cover crops. The yields of corn have been increased 10 to 15 bushels to the acre by the use of legume cover crops. Non-legume cover crops such as rye and buckwheat have not increased yields. Vetch has proved to be the best winter annual as a cover crop for corn land, but is only slightly better than crimson clover.

VARIETY TESTS.—The variety tests have not been conducted long enough at this location to justify conclusions.

Charlotte County Station

The Charlotte County station is located near Charlotte Court House on a Cecil sandy loam soil. The purpose of the station is to conduct experiments with dark fire-cured tobacco and other crops commonly grown on dark tobacco farms. This station was established in 1912 and a line of experiments laid out. In 1923 the experimental data were summarized and a number of new projects were started. For this reason it will be necessary to discuss the results under two heads, viz: (1) old experiments, which include all work done up to 1923; and (2) new experiments, including work done since 1923.

Old Experiments

Reclamation of Worn-Out and Eroded Hillsides.—To determine the practicability of reclaiming worn-out land and to determine the cost of such reclamation. The experiment station was located on a very poor worn-out field. Consequently one of the first problems undertaken was the reclamation of worn-out land. For this work a badly eroded field of 15 acres was chosen. This field was partly grown up in scrub pines and briars and at the beginning of the experiment was incapable of producing 15 bushels of corn to the acre. This field was cleared in 1916 and seeded to cowpeas in 1917, using 300 pounds of 16 per cent. superphosphate to the acre. The peas were plowed under in the fall and rye was seeded, using 300 pounds of 16 per cent. superphosphate to the acre. The rye was plowed down in 1918 and a grass mixture was seeded (orchard grass, tall meadow oat grass, and Alsike clover), using two tons of ground limestone to the acre and 300 pounds of 16 per cent. superphosphate. A good stand of grass was obtained and hay was cut in 1919 and in 1920. The yield averaged a little over one ton to the acre. In 1921 the area was thrown into a regular rotation of corn, wheat, and grass and clover. The yields since that period have been good. The corn averaged 40 to 50 bushels to the acre, the wheat averaged 15 to 20 bushels to the acre, and the hay one and one-half tons to the acre.

For the period of 1916 to 1920 which may be termed the reclamation period of the land, the total cost for labor, teams, seed, and fertilizer was $48.00 per acre. The receipts from hay sold in 1919 and in 1920 was $36.00 per acre, leaving a net cost of $12.00 an acre for improving this land. During this period the productivity of the land was more than doubled and its value more than quadrupled. This is evidenced by the fact that the land could have been purchased at $20.00 per acre at the beginning of the experiment and at the end of it the owner refused to take less than $100.00 an acre for it. This experiment demonstrates that where capital is available to pay the expense of improvement such lands may be profitably reclaimed and brought back into profitable rotations.

Fertilizer Experiments.—The principal work of the experiment station, other than the reclamation work already discussed, has been fertilizer experiments with tobacco and other crops grown on tobacco farms. These experiments show that:

1. Phosphorus is the plant food most needed in soils of this district. Applications of nitrogen and potassium do not pay on tobacco unless phosphorus is also applied.
2. If a high grade tobacco fertilizer is applied to tobacco in a rotation with tobacco, wheat, clover, grass, corn, and crimson clover, profitable yields are made without the application of fertilizers to the crops following tobacco.
3. Lime gives paying results on crops other than tobacco and may be profitably used in a rotation with tobacco when applied a year or two ahead of tobacco. When applied directly to tobacco it has a tendency to lower the grade of the crop.

4. A complete fertilizer containing 3 per cent. nitrogen, 6 per cent. phosphoric acid, and 3 per cent. potash, applied at the rate of 1,000 pounds to 1,500 pounds per acre, gives good results on dark tobacco.
5. For tobacco, nitrogen should be obtained partly from nitrate of soda and partly from some organic material, such as dried blood, tankage, or cottonseed meal, for best results. Acid phosphate and sulphate of potash are good sources of phosphorus and potassium.
6. Profitable crops of tobacco may be produced without potash, but the application of potash with nitrogen and phosphoric acid improves the grade of the crop.
7. A top dressing of nitrate of soda at the rate of 100 pounds per acre gives profitable returns on wheat and grass when the soil is deficient in organic matter.
8. Muriate of potash gives larger yields of tobacco which sells for as much per pound as that produced from sulphate of potash, but the burning quality of tobacco produced with sulphate of potash is better than that produced with muriate of potash or other salts carrying large quantities of chlorine.

Forage Crop Investigations.—Since one of the important problems in a tobacco section is to produce sufficient forage for the animals, considerable work was done with these crops. Some of the more important findings from these investigations are as follows:

1. Soybeans are superior to cowpeas for annual hay production and equal to them for soil improvement purposes.
2. American grown strains of clover, though more susceptible to mildew, give larger yields and last longer than imported kinds.
3. Sweet clover can be successfully grown as a hay crop and soil improver even on thin lands, if such lands are first limed and phosphated.
4. Summer seedings of grass and clover are more profitable than spring seedings.

New Experiments

The following projects were started in 1923 and have been conducted without interruption to date:

1. Sources of nitrogen and potash for dark tobacco;
2. Fertilizer analyses for dark tobacco;
3. Fertilizers for grain and grass rotations with and without lime;
4. Cotton adaptability studies;
5. Variety studies with corn, wheat, oats, rye, tobacco, potatoes, cowpeas, and soybeans.

Sources of Nitrogen and Potash for Dark Tobacco.—To compare the effects of the different carriers of nitrogen and potash commonly used in making tobacco fertilizers. To date there has been no significant difference in the results obtained from the use of nitrate of soda, ammonium sulphate, dried blood, tankage, and fish scrap as sources of ammonia for dark tobacco, either in combination or alone. Dried blood has given the highest returns but its superiority to the other materials mentioned is very slight. Cottonseed meal

and digested garbage tankage have so far proved inferior to the other sources of nitrogen used. These results are not considered conclusive as the tests have been conducted only four years. In three out of the four years of the test, as well as in the average for the four years, muriate of potash has given higher yields and greater crop value per acre than sulphate of potash. However, burning tests show that the burning quality of the tobacco produced with sulphate of potash is superior to that produced with muriate of potash.

Fertilizer Analyses for Dark Tobacco.—To determine the best analysis for dark tobacco fertilizer, when fertilizers are applied at the rate of 1,000 pounds to the acre. All possible single unit combinations of ammonia, phosphoric acid, and potash, between a 10-5-5 and an 8-2-2 fertilizer, are compared. At the present time, when relative costs of making are considered, the 8-3-3 fertilizer seems to be the most practical analysis within the limits of the experiment. In a comparison of rates of application of 8-3-3 fertilizer, 1,000 pounds to the acre has given more profitable returns than either more or less of these fertilizers.

Fertilizers for Grain and Grass Rotations With and Without Lime.—To determine a practicable fertilizer treatment for the corn, wheat, and hay rotation commonly used in the section. In this experiment, 16 per cent. superphosphate, at different rates, is compared with superphosphate and potash and with superphosphate, potash, and nitrogen, both with and without lime. The average results to date show the most profitable returns from the plats receiving lime and a complete fertilizer. However, the benefits from potash are very slight. The benefits from nitrogen are less striking as the experiment progresses and it is believed that after the land has been enriched by several crops of clover, economic production may be maintained with lime and phosphates. Corn shows very little response to lime but wheat and clover seem greatly benefited by it.

Cotton Adaptability Studies.—When this experiment was started, due to the high price of cotton, there was considerable interest in cotton in the county and an insistent demand from local farmers that some work with cotton be started at the station. Variety, fertilizer, and cultural experiments were, therefore, started. These experiments were continued three years. The crop was a complete failure two years and the other year the yields were not sufficient to pay expenses of production. This location is too far north for the successful production of cotton and the experiments were discontinued.

Variety Studies.—To determine the best varieties of the commonly grown crops of the section. Lizard Tail Orinoco has proved to be the best variety of tobacco yet tried for the section. Boone County White, Caseys Pure Bred, and Government No. 182 have been the highest yielding varieties of corn with little difference between them. The Fulcaster types of wheat, such as Stoner, V. P. I. No. 1, and Red Wonder, seem best suited to the section. However, in certain specially good wheat years Fults wheat (commonly called Little Red)

has given exceptionally large yields. Virginia and Laredo soybeans have been the outstanding varieties as far as grain and hay yields are concerned. Abruzzi rye has given higher yields than any other variety tested, and it is also the most promising variety for pasturage and green manure. V. P. I. No. 1 of the winter varieties and Fulghum of the spring varieties are the best yielding oats tested. Money Maker and V. P. I. Green Mountain are the highest yielding varieties of potatoes. Whippoorwill, New Era, and Groit have given better yields of cowpeas than any other varieties tested.

Henry County Station

This station is located near Martinsville on a Cecil clay loam soil. The purpose of the station is to conduct experiments with the field crops commonly grown in the section. However, the investigations do not include tobacco which is grown on a comparatively small scale in the county and it is thought that the results of the tobacco investigations at Chatham will be applicable to this territory. The experiments at this location have been going on since 1920, but they are not conclusive since two very unfavorable seasons have disturbed the results. It has also been found that some of the projects were first located on land which was not uniform in character and these have been relocated.

It is thought that the physical handicaps have been removed so far as possible and that the results in the future will be consistent.

Rates of Liming.—This is a part of an experiment located at two other points in the State which has as its object the determination of the relative effects of different rates of liming various crops on different soil types. Four three-year rotations have been established as follows:

(1) Cowpeas, sapling clover, and oats;
(2) Corn, red clover, and wheat;
(3) Soybeans, barley, and alsike clover; and
(4) Potatoes, rye, and sweet clover.

These rotations are arranged so that each crop is planted on land which has been limed at different rates. Plat 1 receives no lime and the lime is increased at the rate of 300 pounds of ground limestone to the acre for each succeeding plat until Plat 12 reecives 3,300 pounds of ground limestone to the acre. The results of this experiment to date show that:

1. Corn has not been materially affected by liming.
2. The maximum yield of cowpeas is reached when limestone is applied at the rate of 1,200 pounds to the acre. This is maintained to 1,800 pounds of limestone to the acre, after which each corresponding increase in lime causes a decrease in yield.
3. With soybeans the maximum yield is reached when limestone is applied at the rate of 1,800 pounds to the acre. Thereafter increases in the rate of application neither increase nor retard growth.
4. The maximum yield of potatoes is reached when limestone is applied at the rate of 1,500 pounds to the acre. Increased applications above this amount have a tendency to reduce yields.

5. The maximum yield of wheat is reached when limestone is applied at the rate of 1,800 pounds to the acre.
6. Oats do not show either increase or decrease in yield from lime applications.
7. Maximum yields of barley are received where 1,500 pounds of limestone is applied to the acre. Beyond this point crop yields are not affected by increasing the lime applications.
8. The maximum yield of rye is obtained where limestone is applied at the rate of 900 pounds to the acre. Beyond this point there is a slight falling off in yields from increased applications.
9. The maximum yield of red clover is reached at 2,000 pounds of ground limestone per acre.
10. The maximum yield of sapling clover is reached at 2,000 pounds of ground limestone to the acre.
11. The maximum yield of alsike clover is reached at 1,500 pounds of ground limestone to the acre.
12. No sweet clover is obtained on unlimed plats. The yield gradually increases with each increase in application to 2,400 pounds of ground limestone to the acre.

FERTILIZER AND LIME EXPERIMENT.—The purpose of this experiment is to determine in so far as possible the best fertilizer treatment for a corn, wheat, and clover rotation. Particular attention is given to the sources of phosphoric acid. The results of this experiment show that lime pays well in a rotation of this kind. Its most important benefit seems to be in making it possible to grow good crops of clover, as the yields from the corn and wheat vary with the amount of clover on the various plats. Where good stands of clover are obtained, applications of nitrogen have not paid. Where stands of clover are not obtained, which is usually the case on the unlimed plats, applications of 20 pounds of nitrogen to the acre have been profitable. Potash increases yields slightly, but up to the present time the increase has not been sufficient to pay for the fertilizer. The most economical results have been obtained where 300 pounds of 16 per cent. superphosphate (acid phosphate) has been applied to the acre to the corn and wheat crops and lime used in sufficient quantities to insure good crops of clover. Superphosphate (acid phosphate) has proved a more economical source of phosphorus than raw rock phosphate where used both in heavy and in light applications. The application of sulphur and gypsum to the soil has not increased crop yields.

FORAGE CROP EXPERIMENTS.—The purpose of this experiment is to compare the growth of annual summer and winter legumes and to test strains of clover and clover from different sources. Vetch and Austrian winter pea have proved to be the most satisfactory winter annuals for both hay production and soil improvement. The yields of hay and seed have been higher from Austrian winter pea than from vetch. However, some observation of the growth of the winter pea on thin land indicates that vetch is probably superior to it for improving thin soils. Crimson clover has not made satisfactory crops at this location on account of winter killing. It is probably not suited to the stiff, red soils of this section. Better crops of red clover have been obtained from spring seedings in grain than from late summer and early fall seedings on specially

prepared soil. The summer and fall seedings have invariably winter killed. Virginia, Maryland, Tennessee, and Michigan grown clover seed has proved better than that from European clover producing sections. Soybeans when inoculated have given larger yields of both hay and seed than cowpeas. Cowpeas seem better adapted to very thin soils when no fertilizer is used. Velvet beans have not given satisfactory crops.

Legume Experiment.—This is a comparison of the effects of various legumes on the yield of the succeeding crop when seeded in corn at the last working. Vetch has been found to be the most efficient winter legume for this purpose with crimson clover second. Cowpeas have been the most efficient summer legume. With the exception of the three crops mentioned, other legumes tried have not made enough growth to be worthy of consideration. The yields of succeeding crops have been almost directly in proportion to the crops turned under. For this reason, rye, a non-legume, has been more efficient than any of the legumes as a winter cover crop.

Top Dressing Experiment.—To compare nitrate of soda and sulphate of ammonia as top dressings for hay fields and to determine the best dates and rates of making top dressings for the section. To date the nitrate of soda has been slightly more efficient in increasing yields of clover and timothy hay than ammonium sulphate. The best date of application of nitrogenous fertilizers as top dressings for the hay crop when heavy applications have been used (50 pounds of nitrogen to the acre) has been April 1. Where light applications are used (16 to 32 pounds of nitrogen to the acre) April 15 has been the best date. Applications of 30 to 50 pounds of nitrogen to the acre about April 1 have proved most economical.

THE REMOVAL OF SPRAY RESIDUE FROM APPLES

By W. B. Ellett and M. P. Miller

The object of these experiments was to determine the amount of arsenic remaining on some of the commercially grown apples after particular spray treatments, and to study the effect of various treatments recommended for the removal of spray material, and to study other methods which might be efficacious in its removal. Arsenicals are soluble in acids, alkali, and salt solutions with varying degrees of effectiveness. Sulphuric and nitric acids were eliminated because of the effect on and danger to the health of the workers. Hydrochloric acid, being a cheap chemical and obtainable in large quantities, appeared to us the most suitable solvent, and the other acids were eliminated. After trying its effect on some of the apples, it was found that hydrochloric acid would remove the spray material at ordinary temperature and in weak solutions, apparently leaving no taste or injury to the fruit, either after washing in water or leaving the apples to dry after dipping in the acid solutions.

The chemical department solicited the aid of the department of entomology to supply samples of apples for analysis. Several boxes of apples were sent from different points in Virginia with complete data in regard to the amount of arsenate used in the spray mixtures, as well as the dates of application.

Review of Previous Investigations

Garman[1] reports on the amount of arsenic remaining on six samples of cabbage that had been sprayed with Paris green and arsenate of lead. The amount of arsenic per pound would be more than the limit of tolerance allowable under the British standard. Yet he concludes "that the quantity of metals present was so small that accurate determinations could not be expected." In 1902 and again in 1903 he analyzed sprayed cabbage. He reports that he was unable to find a trace of poison present.

Woods[2] gives results on the examination at the time of harvest of the different lots of apples that had been sprayed heavily with arsenate of lead the first week of August, 1913. The apples were thoroughly and carefully washed with water and determinations of lead and arsenic were made in the washings in each lot. He found that this washing removed the arsenic. He concludes that the amount of arsenate of lead that will remain at harvest upon the apples that are sprayed in midsummer is so slight as to have no practical bearing.

O'Kane, Hadley, and Osgood[3] show results of experiments begun in 1912 and concluded in 1916 on the amount of arsenical residues remaining on fruit and vegetables after spraying with arsenate of lead. Ten apple trees were

sprayed and various lots of fruit were picked at periods ranging from 5 to 90 days after spraying. When picked carefully so as not to disturb the poison, the residues were 0.08 to 0.77 milligram As_2O_3 per apple; when picked in ordinary manner, the residues were 0.02 to 0.5 milligram per apple; when picked with cotton gloves and wiped 0.08 to 0.18 milligram per apple. They found that rain and weather influenced the results. When fruit was picked from 75 to 91 days after spraying, 75 per cent. of the residue was removed. Using cotton gloves in picking reduced the residue per fruit one-half where fruit was picked within 3 to 5 days after spraying. This effect diminished when fruit remained longer on the tree.

Robinson and Hartman[4] show that arsenic can be removed from fruit if immersed in a bath containing 2 per cent. hydrochloric acid, with little injury. The same authors[5] state "that the removal of spray residue by wiping has not been satisfactory. Hydrochloric acid has proved to be practically non-injurious to fruit when properly used."

Headden[6] reports that hand and machine wiping have been tried, but the results have not been wholly satisfactory. "There seems to be no evading the necessity of some wet method of removing the residual spray." He recommends a mixture of common salt and sodium carbonate dissolved in water, as a solvent for the spray residue.

The Samples of Apples Analyzed

The orchards from which the apple samples were taken for analysis were sprayed in 1926 according to the following schedule of arsenical sprays (unless otherwise specified):

1. When a majority of the cluster-buds had opened;
2. When the petals had fallen;
3. Three weeks after the petals had fallen;
4. Five weeks after the petals had fallen;
5. About the first week in July.

SAMPLE No. 1.—York Imperial apples from the Green orchard (H. F. Byrd). The orchard received the following poison sprays:

No. 1, consisting of 2 pounds of arsenate of lead and 1¼ gallons of lime-sulphur in 50 gallons of water, applied May 10 to May 25.
No. 2, consisting of 2 pounds of arsenate of lead in 50 gallons of water, applied May 31 to June 17.
No. 3, the same treatment as No. 2, but applied June 21 to July 2.

Rods were used in applying the sprays and thorough spraying was done. The trees were 22 to 28 years of age and it required 10 to 11 gallons of spray solution to cover a tree. Analysis made by the Bureau of Chemistry of the U. S. Department of Agriculture from samples picked on September 13 showed 0.0211 grain of arsenic per pound of fruit. This sample was selected to represent the fruits most heavily coated with spray residue. Spray residue was con-

spicuous on the fruit on September 25, when our sample was taken. Our analysis showed 0.01049 grain of metallic arsenic (0.01664 grain As_2O_3) per pound of fruit at harvest.

Sample No. 2.—York Imperial apples from the orchard of J. W. Sibert. The orchard received the following dust treatments or poison spray:

No. 1, consisting of Sanders green dust S 8, applied May 14 to May 18.
No. 2, consisting of Sanders green dust S 8, applied June 1 to June 8.
No. 3, consisting of Sanders green dust S 8, applied June 25 to June 28.
No. 4, consisting of 1½ pounds of arsenate of lead in 50 gallons of water, applied July 10 to July 17.

The dust used failed to control the codling moth. On account of the severe infestation of codling moth in this orchard, an appilcation of arsenate of lead (No. 4) was applied as noted above. The fruit from this orchard was not suitable for packing, and was sold directly for canning and vinegar purposes. Spray residue was conspicuous on the fruit September 25, at which time the sample was taken. Our analysis showed 0.0237 grain of metallic arsenic (0.0388 grain As_2O_3) per pound of fruit. These apples contained over twice the amount of metallic arsenic allowed.

Sample No. 3.—York Imperial apples from the orchard of Phil Gold, on Apple Pie Ridge. The orchard received the following poison sprays:

No. 1, consisting of 1½ pounds of arsenate of lead and 1¼ gallons of lime-sulphur in 50 gallons of water, applied May 10 to May 25.
No. 2, consisting of 1½ pounds of arsenate of lead and 1¼ gallons of lime-sulphur in 50 gallons of water, applied May 27 to June 15.
No. 3, consisting of 1½ pounds of arsenate of lead, 1½ pounds of bluestone, and 3 pounds of lime in 50 gallons of water, applied June 21 to July 2.

Very thorough spraying was done, and spray residue was very conspicuous on the fruit on September 25, when our sample was taken. Our analysis showed 0.00668 grain of metallic arsenic (0.01095 grain As_2O_3) per pound of fruit remaining on the apples at harvest.

Sample No. 4.—York Imperial apples from the orchard of William Beverley. This orchard received the following poison sprays:

No. 1, consisting of 1½ pounds of arsenate of lead and 1¼ gallons of lime-sulphur in 50 gallons of water, applied May 10 to May 22.
No. 2, consisting of 1½ pounds of arsenate of lead in 50 gallons of water, applied May 27 to June 18.
No. 3, consisting of 1½ pounds of arsenate of lead in 50 gallons of water, applied June 21 to June 30.
No. 4, consisting of 1½ pounds of arsenate of lead in 50 gallons of water, applied July 28.

The trees in this orchard were about 25 years of age, and they were sprayed very heavily, using about 20 gallons of spray solution per tree. Spray

residue was very conspicuous on the fruit on September 25 when our sample was taken. Our analysis showed 0.01328 grain of metallic arsenic (0.02181 grain As_2O_3) per pound of fruit remaining at harvest. The amount of arsenic found was in excess of the limits of tolerance.

SAMPLE No. 5.—York Imperial apples from the orchard of William Beverley, taken from dusted plats. The dust used was Sanders green dust S 8 and four applications were given on the following dates: No. 1 on May 18; No. 2 on June 2; No. 3 on June 25; and No. 4 on July 28. The dust applications were made under ideal conditions, between 5:30 A. M. and 7:00 A. M. The dust was applied from both sides of the trees and on the average 2 pounds of dust per tree was used in each application. Dust residue was not conspicuous on the apples on September 25, when the sample was taken. Our analysis showed 0.000494 grain metallic arsenic (0.000820 grain As_2O_3) per pound of fruit remaining on the apples at the time the sample was harvested.

SAMPLE No. 6.—Stayman Winesap apples from an experimental plat used by W. S. Hough in the Shenandoah Vinegar Company's orchard. This plat of trees received the following poison sprays:

No. 1, consisting of 6 pounds of arsenate of lead and 5 gallons of lime-sulphur in 200 gallons of water applied May 11 to May 13.
No. 2, consisting of 6 pounds of arsenate of lead in 200 gallons of water, applied May 28.
No. 3, consisting of 6 pounds of arsenate of lead in 200 gallons of water, applied June 24.
No. 4, consisting of Volck oil, 1½ per cent. spray solution, applied July 26.

The spraying was done by W. S. Hough, and the spraying was thorough and heavy. The spray residue was not conspicuous on the fruit on September 25. Our analysis showed 0.00472 grain metallic arsenic (0.00774 grain As_2O_3) per pound of fruit remaining on the apples when harvested on September 25.

SAMPLE No. 7.—The apples were secured from Lee Bell, manager of J. Russell Smith's orchard at Round Hill. The orchard received the following spray applications, the proportions not being stated, nor the dates when applied:

No. 1, consisting of arsenate of lead, lime-sulphur, and Kayso.
No. 2, consisting of arsenate of lead, lime-sulphur, and Kayso.
No. 3, consisting of arsenate of lead, lime-sulphur, and Kayso.

Our analysis showed only a trace of arsenic remaining on the fruit.

In addition to the foregoing tests, two lots of apples were sprayed on October 4, 1926, with two different spray mixtures, so that sufficient apples were available to study the effect of the solvents on the removal of arsenic, as well as on the keeping qualities of the apples.

Lot 1 was sprayed with arsenate of lead at the rate of 1½ pounds to 50 gallons of spray mixture. Lot 2 was sprayed with Bordeaux mixture of 3-5-50

strength plus arsenate of lead at the rate of 1½ pounds to 50 gallons. On October 5 it rained late in the afternoon and night, and on October 6 the apples were picked and placed in storage for the investigations which follow. Samples of lots 1 and 2 were treated with solutions of hydrochloric acid, sodium hydrate, sodium hyposulphite, and mixtures of sodium carbonate and sodium chloride and water, and two samples were wiped with cloths. The apples were then dipped in fresh water solutions to remove adhering solutions. After allowing the various samples to dry, they were weighed and analyzed by the modified Gutzeit method. Owing to the fact that different apples would have varying amounts of spray material on them, it was deemed best not only to analyze the apples to determine the amount of arsenic remaining after treatment, but also to analyze aliquots of the solutions used to determine the amount of arsenic removed by the various treatments. This method, we believed, would eliminate the error incident to the different apples having different amounts of spray material on them, and would be more accurate than an average taken from a large number of analyses. On samples 19 and 20 averages were necessarily taken.

Tables 27 and 28 show the result of the chemical analyses. The varying strengths of hydrochloric acid, sodium hydroxide, and salt solutions, as well as the time of contact of the solutions on the fruit are given. Hydrochloric acid of 2.5 per cent. strength will remove over 90 per cent. of the arsenic in

TABLE 27.—APPLES SPRAYED WITH ARSENATE OF LEAD

Lot No.	Treatment	Strength of Solution (per cent)	Time Exposed (Minutes)	Grains of Metallic Arsenic per Pound of Fruit before Treatment	Grains of Metallic Arsenic per Pound of Fruit after Treatment	Per cent. of Arsenic Removed
1	HCl	5	3	.04495	.00345	92.4
2	HCl	5	3	.08424	.00255	96.9
3	HCl	5	2	.09535	.00723	92.3
4	HCl	5	2	.02792	.00365	86.9
5	HCl	5	1	.05307	.00795	82.3
6	HCl	2.5	5	.05561	.00545	91.2
7	HCl	2.5	5	.04627	.00367	92.4
8	HCl	1	5	.04104	.01820	55.5
9	HCl	1	10	.03332	.01031	68.7
10	NaOH	5	3	.03610	.00494	80.6
11	NaOH	5	1	.05308	.00646	86.0
12	Hypo	5	3	.00970	.00810	16.5
13	Hypo	5	5	.06295	.05877	4.6
14	Water	....	5	.07674	.07468	2.7
15	Na_2CO_3+NaCl	8	10	.04183	.00205	96.1
16	Na_2CO_3+NaCl	8	10	.05308	.00234	95.6
17	Na_2CO_3+NaCl	8	10	.03440	.00530	84.6
18	Na_2CO_3+NaCl	8	10	.03227	.00182	94.4
19	Wiped with cloth	....	....	.05308	.04040	23.8
20	Wiped with cloth	....	....	.05308	.03650	31.2

TABLE 28.—APPLES SPRAYED WITH ARSENATE OF LEAD AND BORDEAUX MIXTURE

Lot No.	Treatment	Strength of Solution (per cent)	Time Exposed (Minutes)	Grains of Metallic Arsenic per Pound of Fruit before Treatment	Grains of Metallic Arsenic per Pound of Fruit after Treatment	Per cent. of Arsenic Removed
21	HCl	5	3	.03612	.00112	96.9
22	HCl	5	1	.03534	.00226	93.6
23	HCl	2.5	5	.04755	.00392	91.7
24	HCl	2.5	5	.01594	.00123	92.3
25	HCl	2.5	5	.01273	.00075	96.1
26	NaOH	5	5	.02651	.00412	84.5
27	NaOH	5	3	.01338	.00245	81.6
28	Na_2CO_3+NaCl	8	10	.03300	.00528	84.0
29	Na_2CO_3+NaCl	8	10	.02886	.00179	93.8
30	Water	....	5	.04894	.04739	3.2

five minutes, at a temperature of 70 degrees F., and will lower the arsenic content below the limit of tolerance. Hydrochloric acid in strengths of 2.5 per cent. and 5 per cent. removes all signs of spray residue either when arsenate of lead or when Bordeaux plus arsenate of lead is used. The copper is dissolved also, leaving the fruit clean. One per cent. hydrochloric acid removes over 50 per cent. of the arsenic at ordinary temperatures. However, when higher temperatures were used the fruit did not stand up but turned dark. When a 5 per cent. solution of sodium hydroxide was used, we found that from 80 to 85 per cent. of the arsenic was removed from the fruit that was sprayed with arsenate of lead or with arsenate of lead plus Bordeaux.

Sodium hyposulphite was found unsatisfactory for removing spray residue. Sodium chloride and sodium carbonate, when used in strength of 4 per cent. each in 100 parts of solution, was found effective in removing the spray residue. The apples were allowed to stay in the solution for ten minutes and the solution was kept at a temperature of 100 degrees F. Hand wiping or treatment of apples with water was found unsatisfactory.

Samples of the apples sprayed with arsenate of lead and with arsenate of lead plus Bordeaux were dipped for 5, 10, 15, and 30 minutes in a 2½ per cent. solution of hydrochloric acid; rinsed, dried, and stored for 112 days in cold storage. (These apples had been in cold storage from October 6 to December 14 before treating.) Samples were also treated with a 5 per cent. solution of the acid for 5 minutes and stored for the same length of time. There was no visible injury to any of the fruit. The apples were clean and sound with no trace of spray residue.

Samples of lots numbers 1 and 2 were treated with sodium hydroxide of 2½ per cent. for 5-, 10-, 15-, and 30-minute intervals; and of 5 per cent. strength for 5 minutes. The samples were stored for 108 days. All of the apples in this series were clean and free from spray residue. Although there was

a very slight shriveling in the case of the apples treated with the sodium hydroxide, there was no great difference in these and the checks, which were stored with each set, or the apples treated with the acid.

At the time of removal from storage, some rotten fruit was found scattered through the samples, but in each case the rot was traced to an abrasion and obviously had no relation to the treatment.

These studies show that hand wiping may not be depended upon to satisfactorily remove spray residue from apples carrying an excess of arsenic. It is improbable that any mechanical wiper can be devised that will be more successful than wiping by hand. The wipers themselves will become contaminated with the arsenic after a certain period of usage. It would seem, therefore, unwise for the grower to invest large amounts of money in costly mechanical wipers. Many of the wipers on the market will certainly improve the appearance of the fruit, but there is no evidence that they will effectually remove the arsenic.

It is obvious, therefore, that chemical means must be adopted for the removal of arsenic and other spray residues where the fruit is subjected to late and heavy sprays. These studies show that this method is altogether feasible provided the mechanical difficulty of applying the chemical methods can be overcome. It only remains to devise a mechanical apparatus to dip, rinse, and dry the fruit without adding too much cost to the other operations of grading and packing.

Literature Cited

[1] Garman, H. Insects injurious to cabbage. Kentucky Agricultural Experiment Station Bulletin 114; 1904.

[2] Woods, Charles D. Field experiments; analysis for poison of apples sprayed with arsenate of lead in midsummer. Maine Agricultural Experiment Station Bulletin 224; 1914.

[3] O'Kane, W. C., Hadley, Jr., C. H., and Osgood, W. A. Arsenical residues after spraying. New Hampshire Agricultural Experiment Station Bulletin 183; 1917.

[4] Robinson, R. H., and Hartman, Henry. The removal of spray residue from apples. Oregon Agricultural Experiment Station Circular of Information 11; 1926.

[5] Robinson, R. H., and Hartman, Henry. A progress report on the removal of spray residue from apples and pears. Oregon Agricultural Experiment Station Bulletin 226; 1927.

[6] Headden, William P. Removal of arsenate of lead from sprayed fruit. Colorado Agricultural Experiment Station Bulletin 63; 1926.

WINTER FATTENING OF STEERS

By R. E. Hunt

In some sections of southwestern Virginia but more particularly in the Shenandoah Valley and northern Virginia there is a real interest in the fattening of calves and yearlings. In these sections farmers produce an abundance of hay and corn and they wish to market these products by feeding them to steers in the most economical way. The feeding rations will consist of corn, cottonseed meal, hay, and silage in varying amounts. In some cases one or possibly two of these feeds will be omitted entirely, but the chief question in mind is the relative amounts and proportions of these different feeds to make most economical gains and to furnish the cheapest rations for fattening these classes of livestock.

Feeding Experiments for the Winter of 1920-21

The object of this experiment was to determine the advisability of using corn stover silage in place of corn silage and the substitution of molasses for corn, assuming that 3 pounds of molasses have an equivalent feeding value to 2 pounds of corn.

Care of Animals.—Small lots were used with an open shed for shelter. This shed was closed on three sides and open to the south, allowing about 100 sq. ft. ground area per steer. Water was available at all times and there was sufficient manger space for the steers. The lots used for this year are the same as were used in the succeeding years.

The Steers.—The steers were purchased on the Roanoke stock yards and had been shipped in from Canada. They were grade Shorthorns of fair quality.

The Weighings.—At the beginning of the feeding period the steers were given identification marks by the use of notches in the ear and each steer was weighed individually each week. All weights were taken about the middle of the day. The method of weighing was the same for all three years.

Rations Fed per Head per Day:

Lot I. 4 pounds corn, 4 pounds cottonseed meal, 30 pounds corn silage;
Lot II. 4 pounds corn, 4 pounds cottonseed meal, 3 pounds molasses, 30 pounds corn stover silage;
Lot III. 6 pounds corn, 4 pounds cottonseed meal, 30 pounds corn stover silage;
Lot IV. 4 pounds cottonseed meal, 9 pounds molasses, 30 pounds corn stover silage.

The corn was of good quality No. 2 commercial grade. The cottonseed was of good grade 38.62 per cent. protein meal. The molasses was ordinary black

strap feeding molasses. The corn silage was of good quality and from corn that made about 4½ bushels of grain corn per ton of silage. The corn stover silage was corn stover from which the corn had been removed and as soon as the corn had been husked the stover was run through the silage cutter, and sufficient water was added to make it pack in the silo. This corn stover silage was of fair quality rather low in palatability, dark in color, but it proved to be quite an excellent way of taking care of a large amount of corn stover that could not be stored or used successfully in other ways.

TABLE 29.—SHOWING DATA ON THE FEEDING TRIALS FROM DECEMBER 18, 1920 TO APRIL 16, 1921 (119 DAYS)

	Lot 1	Lot 2	Lot 3	Lot 4
	Corn, Cottonseed Meal, and Corn Silage	Corn, Cottonseed Meal, Molasses, and Corn Stover	Corn, Cottonseed Meal, and Corn Stover	Molasses, Cottonseed Meal, and Corn Stover
Steers per lot	9	9	9	9
Av. initial weight in pounds	669	649	658	656
Av. final weight in pounds	888	837	867	862
Av. total gain in pounds	219	188	207	206
Av. daily gain in pounds	1.84	1.58	1.75	1.73
Total feed consumed per lot:				
Corn (pounds)	4,284	4,284	5,712	
Cottonseed meal (pounds)	4,284	4,284	3,808	3,808
Molasses (pounds)		3,213		8,568
Corn stover silage (pounds)		32,130	28,560	28,560
Corn silage (pounds)	32,130			
Av. daily ration per steer:				
Corn (pounds)	4	4	6	
Cottonseed meal (pounds)	4	4	4	4
Molasses (pounds)		3		9
Corn stover silage (pounds)		30	30	30
Corn silage (pounds)	30			
Feed per 100 pounds of gain:				
Corn (pounds)	217	253	342	
Cottonseed meal (pounds)	217	253	228	230
Molasses (pounds)		190		519
Corn stover silage (pounds)		1,901	1,710	1,730
Corn silage (pounds)	1,630			
Cost of feeds, per lot	$415.55	$346.47	$287.88	$342.15
Cost of cattle at $7.00 per cwt.	421.40	408.80	368.48	367.22
Total cost	836.95	755.27	656.36	709.37
Cost per cwt. of gain	21.09	20.50	17.24	20.76
Selling value at $7.22 per cwt.	577.02	543.95	500.07	497.89
Loss per steer	28.88	23.48	19.53	26.43

PRICE OF FEEDS: Corn $1.23 per bushel; cottonseed meal $60.00 per ton; molasses 26c. per gallon; corn stover silage $3.50 per ton; corn silage $12.00 per ton.

RESULTS.—Corn stover silage proved slightly more economical than did corn silage. This will be true when corn silage is high in price due to high-priced corn. The gains from these rations were practically the same with the exception of Lot II where there was less gain than that of the other lots. Six pounds of corn, 4 pounds of cottonseed meal, and 30 pounds of corn stover silage proved very much cheaper than did 4 pounds of cottonseed meal, 9 pounds of molasses, and 30 pounds of corn stover silage, thus showing for economical returns 5 pounds of corn was cheaper than 9 pounds of molasses; however, the gains made are the same.

In this experiment Lot III requires a margin of $1.41 to break even, while Lot I would require $3.47 margin. Under ordinary conditions with a margin of from $2.00 to $2.50 per cwt. Lot III would have made a good profit, while Lot I would have shown a decided loss.

FEEDING EXPERIMENTS FOR THE WINTER OF 1921-22

The feeding experiments were carried on this season to determine the advisability of feeding different amounts of cottonseed meal, along with a basal ration of 8 pounds of corn and 25 pounds of silage.

THE STEERS.—The steers were purchased in Monroe County, West Virginia, and were fair quality Shorthorns, Herefords, and Aberdeen-Angus, with Shorthorns predominating. The breeds were divided in such a way that there was an equal number of each breed in each lot.

RATIONS FED PER HEAD PER DAY.—The following rations were fed to the steers:

Lot I. 8 pounds corn, 4 pounds cottonseed meal, 25 pounds silage;
Lot II. 8 pounds corn, 3 pounds cottonseed meal, 25 pounds silage;
Lot III. 8 pounds corn, 2 pounds cottonseed meal, 25 pounds silage;
Lot IV. 8 pounds corn, 1 pound cottonseed meal, 25 pounds silage.

RESULTS.—The steers in Lot I which were fed 4 pounds of cottonseed meal per day gained more pounds than did the others. The rate of gain per day was almost in direct proportion to the amount of cottonseed meal fed. The additional cottonseed meal did not produce sufficient additional gains to make it profitable. The quality and finish of the steers receiving the larger quantity of cottonseed meal were somewhat superior in comparison with the other lots, but the difference was not enough to make it profitable. With current prices of feed, the cost of 100 pounds of gain in Lot I with 4 pounds of cottonseed meal was $12.19; in Lot II with 3 pounds of cottonseed meal, $11.92; in Lot III with 2 pounds of cottonseed meal it was $11.79; and in Lot IV with 1 pound cottonseed meal it was $10.67.

TABLE 30.—SHOWING DATA ON THE FEEDING TRIALS FROM NOVEMBER 18, 1921 TO APRIL 7, 1922 (140 DAYS).

	Lot 1 Corn, Cottonseed Meal and Corn Silage	Lot 2 Corn, Cottonseed Meal and Corn Silage	Lot 3 Corn, Cottonseed Meal and Corn Silage	Lot 4 Corn, Cottonseed Meal and Corn Silage
Steers per lot	9	9	8	8
Av. initial weight (pounds)	650	650	668	660
Av. final weight (pounds)	964	943	938	928
Av. total gain (pounds)	314	293	270	268
Daily gain (pounds)	2.24	2.09	1.93	1.91
Total feed consumed (per lot):				
Corn (pounds)	10,080	10,080	8,960	8,960
Cottonseed meal (pounds)	5,040	3,780	2,240	1,120
Corn silage (pounds)	31,500	31,500	28,000	28,000
Av. daily ration (per head):				
Corn (pounds)	8	8	8	8
Cottonseed meal (pounds)	4	3	2	1
Corn silage (pounds)	25	25	25	25
Feed per 100 pounds of gain:				
Corn (pounds)	355	382	415	418
Cottonseed meal (pounds)	178	143	104	52
Corn silage (pounds)	1,114	1,194	1,294	1,306
Cost of feed (per lot):	$344.52	$315.54	$254.54	$228.96
Cost of cattle at $6.20 per cwt.	362.70	362.70	331.08	327.36
Total cost	707.22	678.24	585.80	556.32
Cost per cwt. gain	12.19	11.92	11.79	10.67
Selling value at 6c. per pound	520.80	509.40	445.20	450.00
Loss per steer	20.71	18.76	16.97	13.89

PRICES OF FEEDS: Corn 74½c. per bushel; cottonseed meal $46.00 per ton; corn silage $6.00 per ton.

Using the above values it will take a margin of $1.30 in the case of Lot IV and gradually increase until Lot I will require a margin of $1.95 per hundred pounds to break even.

FEEDING EXPERIMENTS FOR THE WINTER 1922-23

The object of these experiments was to determine the advisability of substituting one pound of cottonseed meal for one pound of corn in feeding ration of calves.

THE ANIMALS.—The steers were calves purchased at the Kansas City yards and shipped to Virginia. They were of fair qualiity, Shorthorn and Hereford grades. The average weight of the calves was about 450 pounds.

RATIONS PER HEAD PER DAY.

Lot I. 1 pound corn, 3 pounds cottonseed meal, 8 pounds corn silage, 4 pounds hay;

Lot II. 2 pounds corn, 2 pounds cottonseed meal, 8 pounds corn silage, 4 pounds hay;
Lot III. 3 pounds corn, 1 pound cottonseed meal, 8 pounds corn silage, 4 pounds hay;
Lot IV. 4 pounds corn, 8 pounds corn silage, 4 pounds hay.

It will be noted from these rations that the silage and hay was identically the same in each lot, that the total grain ration was four pounds, ranging in proportion from one pound corn and three of cottonseed meal to four pounds corn with no cottonseed meal. On January 10th corn silage was increased to 10 pounds; and two pounds of corn were added to each steer's ration on Feb-

TABLE 31.—SHOWING DATA ON THE FEEDING TRIALS FROM NOVEMBER 29, 1922 TO MAY 30, 1923—(182 days)

	Lot 1	Lot 2	Lot 3	Lot 4
	Corn, Cottonseed Meal, Corn Silage, and Hay	Corn, Cottonseed Meal, Corn Silage, and Hay	Corn, Cottonseed Meal, Corn Silage, and Hay	Corn, Corn Silage, and Hay
Steers per lot	8	9	9	9
Av. initial weight (pounds)	448	458	465	456
Av. final weight (pounds)	772	766	726	700
Av. total gain (pounds)	324	308	261	244
Total feed consumed per lot:				
Corn (pounds)	6,936	9,450	10,386	11,466
Cottonseed meal (pounds)	4,369	3,276	1,638	....
Corn silage (pounds)	13,888	15,624	15,624	15,624
Hay (pounds)	6,944	7,812	7,812	7,812
Av. daily ration per steer:*				
Corn (pounds)	1	2	3	4
Cottonseed meal (pounds)	3	2	1	....
Corn silage (pounds)	8	8	8	8
Hay (pounds)	4	4	4	4
Feed per 100 pounds of gain:				
Corn (pounds)	116	181	284	378
Cottonseed meal (pounds)	168	118	69	....
Corn silage (pounds)	536	563	665	711
Hay (pounds)	268	282	332	355
Cost of feeds per lot	$375.97	$410.89	$385.26	$262.38
Cost of cattle at $8.15	291.77	355.94	341.49	334.15
Total cost	667.74	766.83	726.75	696.53
Cost per cwt. gain	14.50	14.82	16.40	16.50
Selling value at $7.87	486.05	542.44	513.91	495.81
Loss per steer	22.71	26.93	23.65	22.30

PRICE OF FEEDS: Corn $38.00 per ton; cottonseed meal $53.00 per ton; corn silage $6.00 per ton; hay $25.00 per ton.

*Note: Corn silage and hay were increased on January 10th to 10 pounds. Also 2 pounds of corn were added to each steer's ration on Februaty 21st and from March 20th increased as fast as steers would take it, averaging approximately 10 to 11 pounds each from March 20th to May 30th.

ruary 21st. Beginning on March 20th the corn was increased to 10 or 11 pounds which was the maximum amount that the calves would consume.

RESULTS.—The ration where 3 pounds of cottonseed meal were used gave the greatest total gain and the lowest cost per cwt. of gain. The calves in this lot were in very much better condition, maintained better appetite, and would consume more feed than those in any of the other lots. Calves in Lot IV, without cottonseed meal, went off feed two or three times in the latter part of the experiment. The gains were less than those of the other lots. Lot III with 1 pound of cottonseed meal went off feed but not quite as badly as did those in Lot IV. The gains were slightly more than the calves of Lot IV. In the feeding of calves two or three pounds of cottonseed meal per head per day gave decidedly better results from the viewpoint of gains, finish, and quality than was the case of Lots III and IV with one pound of cottonseed meal, or no cottonseed meal.

The neecssary margin in the feeding of these calves ranged from $2.66 in case of Lot I to $2.97 in the case of Lot III.

Summary

1. In feeding steers, 3 pounds of molasses will give equivalent gains to 2 pounds of corn.
2. Corn stover silage may be used as an economical feed for the fattening of steers.
3. For yearling steers where corn and corn silage were fed, 1 pound of cottonseed meal proved more economical than a larger quantity of cottonseed meal.
4. A ration of 8 pounds of corn, 1 pound of cottonseed meal, and 25 pounds of silage was not sufficient to make satisfactory finish on steers.
5. Calves will consume much less roughage than will yearlings and make relatively more grain.
6. A ration consisting of 4 pounds of hay, 8 pounds of corn silage, 3 pounds of cottonseed meal, and 1 pound of corn, finally increased up to full feed of corn, makes a very satisfactory ration in the feeding of calves.
7. It is necessary to provide some form of protein-rich concentrate in the successful feeding of calves.

METEOROLOGICAL RECORDS FOR THE YEARS 1919 TO 1927, INCLUSIVE

By H. L. Price, Observer

READING OF MAXIMUM AND MINIMUM THERMOMETERS 1919

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	58	36	49	32	55	32	37	20	68	44	90	54	81	64	80	65	72	45	85	45	71	55	48	24
2	59	39	49	16	56	27	47	25	76	47	82	58	87	49	76	50	73	43	85	54	58	45	45	24
3	41	19	49	27	60	27	62	24	75	36	81	58	90	57	79	49	75	40	84	59	57	37	41	28
4	20	1	47	33	65	31	58	30	83	44	81	55	89	59	85	54	80	42	84	64	64	40	32	22
5	18	1	46	27	60	31	60	41	82	52	84	62	90	57	89	60	82	52	86	55	57	32	40	29
6	21	0	40	18	52	27	72	30	71	58	81	60	90	63	84	67	86	50	77	62	64	27	40	27
7	44	4	47	20	59	31	76	39	78	53	84	51	88	59	88	60	86	52	73	53	57	35	56	32
8	38	22	44	32	58	33	74	40	82	57	80	53	80	64	83	67	83	53	62	38	47	38	41	38
9	30	25	34	24	55	36	83	40	80	58	86	58	80	58	81	55	84	55	60	47	52	40	58	39
10	40	12	32	18	49	30	73	54	77	53	83	57	80	55	77	53	85	59	84	55	53	31	47	24
11	45	23	40	16	48	37	68	50	64	53	82	58	80	62	78	60	83	65	84	50	52	45	29	12
12	43	28	52	26	60	25	66	35	65	34	81	58	88	51	70	63	71	56	67	61	60	49	57	25
13	54	19	45	30	64	29	66	40	63	45	82	55	84	50	78	57	78	35	63	44	60	33	58	34
14	48	26	57	35	59	39	67	37	58	46	85	57	88	63	80	60	81	36	72	43	40	19	21	20
15	43	30	45	30	45	31	72	42	69	47	84	59	88	63	85	56	84	45	75	55	46	25	27	12
16	53	20	37	26	53	35	72	51	77	41	81	60	85	63	85	65	82	48	82	55	53	21	38	19
17	40	29	43	24	66	45	60	38	72	53	69	52	80	64	81	62	79	43	74	54	50	22	24	23
18	51	43	38	27	62	35	48	34	69	40	83	65	77	65	80	57	75	45	57	47	53	25	20	12
19	53	29	47	19	52	35	62	25	70	37	81	60	78	66	80	56	83	55	66	38	30	27	26	16
20	57	25	44	22	62	30	71	31	71	57	87	59	78	64	83	54	85	59	65	33	41	21	38	15
21	64	25	49	27	68	32	73	41	68	50	85	61	85	64	83	56	84	55	67	51	50	19	39	13
22	63	26	47	25	63	42	71	31	67	42	79	57	82	65	80	63	83	60	66	50	50	26	39	14
23	52	40	47	34	60	29	75	49	67	43	75	61	86	65	85	57	78	59	63	49	51	38	30	20
24	49	32	55	24	66	29	68	50	72	36	67	58	87	58	86	54	71	42	56	51	51	32	27	26
25	54	27	51	36	69	31	46	28	73	45	74	57	87	64	79	58	77	35	65	52	50	24	30	14
26	51	39	46	22	68	38	54	30	82	48	82	63	89	60	73	47	79	40	82	54	60	49	38	12
27	51	26	57	19	62	34	67	28	78	57	84	63	88	63	76	42	75	39	80	57	60	44	39	30
28	50	25	58	27	43	29	74	35	80	55	75	60	86	66	74	44	73	34	79	54	44	41	39	26
29	46	33	----	----	42	28	69	40	80	54	76	59	86	68	76	54	81	31	71	50	48	34	35	22
30	57	28	----	----	61	42	60	45	85	52	73	47	86	66	71	52	86	34	72	48	45	38	39	22
31	53	35	----	----	52	30	----	----	86	52	----	----	89	54	75	55	----	----	80	54	----	----	43	17
Average	46.6	24.4	46.2	25.6	57.9	32.6	65.0	36.7	73.6	48.0	80.6	57.7	84.7	60.9	80.0	56.8	79.8	46.9	73.1	50.9	52.5	33.7	38.2	22.2

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1920

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	33	31	27	10	34	12	63	39	52	34	75	43	86	64	62	59	73	64	47	41	70	43	46	38
2	33	12	49	25	44	19	63	54	51	31	75	52	68	60	71	53	70	48	50	34	60	38	49	35
3	22	1	50	32	48	20	65	35	55	30	69	55	82	64	69	50	64	56	52	30	57	37	55	25
4	20	8	46	32	40	30	60	44	63	32	60	59	81	60	69	50	68	49	64	36	63	29	52	33
5	22	1	31	26	38	22	57	30	60	39	63	51	74	47	74	49	62	52	58	48	64	35	50	33
6	31	4	35	22	26	11	43	21	65	42	68	45	74	52	72	50	52	49	59	33	67	21	41	31
7	46	23	34	25	23	13	44	33	65	44	77	39	79	63	75	60	70	55	57	30	65	30	53	31
8	53	37	33	31	38	5	52	35	61	49	75	45	77	58	69	57	66	50	58	30	68	50	41	31
9	61	43	44	25	47	16	55	38	67	34	79	47	78	53	74	57	69	59	63	34	63	44	44	22
10	45	24	50	35	52	26	54	30	72	34	82	50	73	54	77	64	70	60	57	37	57	46	42	27
11	42	20	44	28	52	36	66	24	71	42	83	58	78	61	74	64	76	53	68	37	49	37	47	31
12	38	22	44	25	55	39	64	37	65	45	70	60	79	58	78	63	75	60	70	37	45	25	53	24
13	38	22	35	22	54	24	50	30	58	56	80	59	78	56	73	61	73	65	64	35	36	11	52	35
14	38	28	48	21	45	25	50	25	58	45	83	67	74	57	70	65	76	51	64	35	42	9	61	42
15	42	22	19	15	64	25	59	23	61	27	73	60	77	60	69	64	76	48	76	36	38	31	44	30
16	35	26	20	3	55	45	57	37	61	32	84	57	79	57	73	65	75	53	70	37	35	30	37	25
17	35	21	41	10	57	41	63	35	62	35	73	63	75	56	70	63	74	42	65	40	34	25	37	25
18	25	15	36	22	67	37	60	38	59	49	70	57	73	63	66	62	75	38	68	40	43	22	33	21
19	50	16	30	25	62	38	56	41	67	51	70	55	74	64	67	62	73	42	67	49	57	24	42	16
20	50	26	39	16	50	30	56	49	66	52	59	53	78	58	75	60	64	53	67	45	62	31	44	16
21	47	36	35	29	53	27	72	48	67	55	67	53	80	63	72	59	63	58	72	43	66	25	39	19
22	48	27	47	34	62	22	76	37	78	41	71	53	81	55	70	62	71	50	72	44	54	28	35	27
23	37	27	47	37	63	24	70	45	77	43	69	53	84	57	78	58	71	56	64	41	44	34	47	33
24	49	34	42	29	63	29	65	40	72	47	78	47	83	65	73	51	69	61	70	41	42	34	36	25
25	37	25	30	17	60	39	60	35	59	52	75	45	83	61	77	55	69	60	70	33	44	34	33	25
26	26	20	21	14	69	50	50	30	57	45	76	50	68	51	69	60	62	60	72	33	47	33	28	18
27	44	24	28	9	69	45	59	42	63	44	74	49	70	49	63	56	66	57	66	58	40	27	41	24
28	39	30	35	11	68	34	57	41	68	44	70	50	71	47	72	59	65	58	45	44	46	35	35	24
29	39	18	36	22	65	45	54	36	79	49	74	50	80	46	73	58	63	48	40	29	42	33	42	15
30	53	22			59	39	50	36	72	49	81	62	85	50	80	62	47	45	49	28	42	32	49	24
31	50	23			68	30			73	46			79	52	71	58			52	32			47	31
Average	39.6	22.2	37.1	22.5	53.2	29.0	58.3	36.3	64.6	42.5	73.4	52.9	77.5	56.8	71.8	58.6	68.2	53.3	61.8	37.7	51.4	31.1	43.7	27.0

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1921

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	57	30	33	27	58	22	58	34	58	39	72	48	84	63	80	63	80	59	69	37	60	46	65	30
2	54	40	34	25	68	26	68	26	60	33	76	58	81	63	79	64	80	59	74	37	52	38	58	43
3	46	33	36	29	60	43	78	38	57	43	80	56	80	65	79	65	78	58	70	56	47	30	57	39
4	60	24	51	20	50	29	76	36	54	42	69	56	81	63	74	60	73	60	56	42	51	35	50	30
5	55	35	46	26	71	29	71	39	51	44	68	58	80	62	74	64	79	60	58	41	58	38	34	25
6	44	26	54	37	71	35	69	41	52	40	72	43	70	63	79	62	81	60	71	36	59	24	46	28
7	55	24	60	28	75	45	68	55	65	40	80	48	75	65	69	65	76	63	74	38	64	33	55	32
8	53	38	60	40	70	46	65	54	69	36	80	53	70	63	76	64	76	61	64	40	61	33	45	31
9	39	29	56	36	65	51	64	51	74	35	64	56	84	65	75	47	71	65	66	29	50	40	44	28
10	42	27	57	34	62	31	55	36	79	38	73	58	80	64	77	58	78	62	77	38	50	34	51	16
11	36	4	42	31	63	27	46	23	67	48	76	62	79	66	80	56	73	61	74	43	52	23	50	34
12	35	25	34	29	59	35	63	24	64	50	74	63	80	65	80	54	81	59	67	40	47	27	47	34
13	27	5	59	29	75	41	72	32	73	51	84	61	78	63	77	62	80	52	58	30	40	18	43	29
14	35	16	62	35	69	42	68	42	75	49	81	61	73	65	73	62	83	55	64	30	51	34	48	32
15	36	22	64	29	73	50	76	38	75	45	79	51	79	61	74	54	80	61	65	29	54	37	39	30
16	43	12	70	29	66	50	67	50	68	50	88	55	79	64	60	58	86	56	68	30	51	28	45	25
17	43	24	62	42	66	34	68	48	69	36	70	58	79	63	82	58	87	58	65	28	72	43	54	28
18	33	14	51	21	67	44	40	32	77	39	78	68	82	61	80	63	72	66	67	34	72	41	58	29
19	25	3	37	26	67	44	59	33	76	45	67	62	77	64	79	58	85	50	50	34	68	52	43	23
20	44	13	42	25	76	54	69	30	74	46	72	54	77	65	85	55	82	56	50	35	61	30	53	20
21	51	27	31	12	80	53	74	46	74	58	81	58	78	56	85	62	82	65	53	33	59	30	50	33
22	52	34	44	21	68	41	70	50	80	50	74	64	78	56	78	56	76	58	75	26	68	25	42	19
23	56	40	42	24	47	36	66	50	82	56	85	64	76	49	65	54	78	52	75	38	60	30	49	20
24	45	8	35	18	46	39	82	43	56	48	88	65	76	56	71	54	76	51	79	36	68	41	53	28
25	40	21	35	20	74	36	85	42	64	49	84	65	67	60	73	53	76	53	79	34	52	38	52	30
26	32	16	40	19	78	43	86	46	64	60	77	62	71	61	71	58	78	58	82	40	62	37	36	19
27	41	18	43	32	80	46	72	55	70	59	85	64	81	61	72	44	72	55	76	41	57	43	45	28
28	47	4	52	23	76	40	56	50	80	58	76	61	85	61	69	52	78	58	66	40	55	32	45	17
29	39	16			48	24	65	48	68	58	80	62	75	65	80	62	82	55	47	44	46	30	40	29
30	49	30			52	20	55	38	65	60	83	66	84	66	84	56	75	54	65	42	55	30	39	17
31	43	31			67	41			72	58			84	65	83	59			64	44			49	18
Average	43.8	22.1	47.6	27.4	66.0	38.6	66.9	40.8	68.1	47.2	77.2	58.7	78.2	62.2	76.2	58.1	78.5	58.0	66.7	36.8	56.7	34.0	47.9	27.3

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1922

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	45	15	40	21	39	22	59	36	69	36	69	58	86	60	80	62	86	56	80	40	65	32	65	29
2	29	9	57	34	46	27	60	32	70	43	74	61	86	62	78	53	80	60	80	40	68	38	63	44
3	46	18	47	33	44	30	69	33	66	54	78	62	85	63	78	57	87	60	84	38	61	46	58	47
4	56	32	44	26	39	30	76	36	65	50	80	55	76	59	78	56	86	60	84	46	59	48	50	37
5	55	44	40	32	55	32	73	43	66	50	76	61	74	53	83	53	86	58	86	43	62	37	56	42
6	46	24	44	33	69	25	58	40	74	52	83	60	80	58	85	55	87	54	79	46	68	31	55	29
7	47	23	39	21	60	38	72	41	75	55	83	59	82	55	85	65	88	54	79	58	63	54	46	32
8	36	23	31	18	45	31	83	43	79	41	81	60	74	59	83	64	86	52	77	57	57	38	66	36
9	46	28	37	15	48	25	78	55	80	47	76	65	83	60	79	57	86	55	64	56	52	39	59	44
10	50	26	49	33	50	35	83	54	80	51	80	64	89	58	75	57	84	64	71	57	61	19	45	32
11	41	29	67	33	48	41	74	64	80	51	80	59	89	60	70	57	84	59	60	39	65	22	37	23
12	31	15	61	36	55	30	73	49	81	69	80	65	89	60	75	50	75	54	62	42	67	30	49	33
13	31	10	58	36	61	31	78	42	74	58	77	51	85	63	73	61	78	44	58	30	62	34	37	19
14	32	13	42	27	74	40	82	60	75	45	82	56	80	63	75	63	82	46	52	32	68	32	46	33
15	45	13	34	27	68	38	78	54	74	40	82	61	79	64	79	64	85	49	72	43	56	46	54	33
16	39	30	19	14	53	31	62	42	72	41	87	55	81	64	84	59	84	50	78	50	49	34	41	29
17	32	25	28	10	54	34	75	50	60	53	87	62	83	65	84	56	70	51	68	53	60	19	47	39
18	43	31	41	21	50	32	70	54	60	54	80	64	83	63	85	56	70	49	60	38	59	29	41	30
19	50	32	45	33	54	36	58	40	69	48	77	62	80	61	82	55	73	43	63	25	62	44	39	20
20	49	33	66	37	51	35	58	35	75	41	78	63	80	61	75	53	75	41	68	29	58	36	31	14
21	55	35	59	41	35	31	58	28	80	45	79	58	81	60	75	42	73	45	60	34	42	31	47	26
22	50	31	69	36	42	28	52	37	79	51	77	56	84	56	80	55	78	46	70	40	38	27	41	24
23	36	27	69	38	61	25	56	27	79	51	79	43	85	62	85	58	81	42	60	34	52	28	54	24
24	34	21	56	36	72	32	63	26	78	55	84	46	81	62	78	60	80	45	55	37	48	35	57	23
25	30	12	52	28	73	33	69	35	80	51	89	56	86	58	81	64	72	49	62	31	40	23	58	27
26	26	9	50	36	67	34	70	50	79	52	86	56	83	66	71	63	66	43	59	46	41	23	65	26
27	29	17	68	38	61	50	69	50	70	49	84	59	82	65	79	62	80	40	68	31	37	27	51	27
28	39	21	58	37	70	48	59	36	66	49	85	60	86	63	76	43	79	48	69	34	34	25	50	29
29	45	21			73	50	60	36	72	39	88	62	85	63	79	45	78	46	79	33	51	15	36	26
30	45	17			72	42	68	29	74	40	86	59	80	62	82	50	79	37	78	33	60	22	40	16
31	45	11			68	43			71	51			82	62	79	60			69	34			39	23
Average	41.4	22.4	48.9	29.6	56.7	34.2	67.9	41.9	73.8	48.4	80.7	58.6	82.5	60.0	79.2	56.5	79.9	50.0	69.5	40.8	55.5	32.1	49.1	29.5

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1923

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	45	30	62	45	45	29	45	10	74	36	82	56	71	52	80	61	80	52	67	38	53	26	48	36
2	49	20	62	47	64	26	58	17	76	38	86	55	64	55	85	62	79	45	69	34	47	21	52	24
3	49	31	57	38	71	38	62	31	76	45	87	57	81	54	86	60	86	52	69	43	49	22	59	44
4	38	28	40	27	68	44	66	39	73	36	88	50	82	55	85	62	87	58	69	40	46	40	48	33
5	51	30	33	23	62	36	62	46	69	45	82	57	86	57	85	65	85	64	66	41	54	44	48	41
6	52	23	26	15	48	31	59	38	76	37	82	63	79	60	87	64	82	64	59	43	52	40	48	32
7	45	28	36	17	39	30	68	29	78	42	84	62	80	64	85	67	80	63	51	37	48	34	52	27
8	48	32	47	8	39	19	64	40	67	41	78	60	77	63	82	62	75	59	66	27	44	32	63	25
9	47	27	50	23	52	17	52	28	60	31	70	48	82	49	83	63	79	45	67	28	42	21	65	41
10	33	26	46	33	51	32	61	24	59	32	81	42	87	53	83	62	74	50	71	21	55	25	62	50
11	43	15	41	29	46	36	69	28	71	29	72	44	88	56	83	63	76	50	78	32	60	32	59	42
12	47	30	35	26	74	33	72	30	73	43	72	51	88	65	81	66	80	56	81	32	52	28	58	18
13	44	25	64	29	71	45	67	49	66	53	59	50	82	63	80	63	73	56	82	35	57	33	62	37
14	54	27	60	29	51	29	60	33	66	45	76	45	84	64	85	55	70	42	78	38	65	23	55	21
15	44	33	37	13	52	29	50	31	74	52	80	50	88	63	84	59	66	46	80	40	55	28	35	11
16	34	23	25	8	58	41	61	29	76	55	84	52	80	61	85	52	65	42	72	42	56	34	58	22
17	32	14	32	13	52	25	57	35	66	48	86	55	81	60	81	66	68	44	62	50	46	32	54	32
18	50	18	28	5	59	25	55	30	70	36	86	58	78	50	74	61	77	40	71	41	55	30	57	20
19	49	32	32	10	48	19	69	42	81	45	86	57	83	49	83	62	78	57	70	52	52	29	53	21
20	43	25	40	17	45	11	76	35	80	54	88	56	86	52	82	52	83	58	59	45	55	22	61	42
21	59	32	50	14	58	21	71	39	73	46	89	58	86	57	86	54	75	63	61	30	64	25	66	39
22	54	33	40	28	68	35	72	50	72	45	85	63	84	63	75	63	72	61	59	30	64	35	65	41
23	34	20	33	20	73	55	75	58	70	51	88	60	78	53	64	52	83	62	51	34	53	43	59	41
24	41	19	46	10	56	31	70	45	55	49	86	63	76	59	74	42	83	56	41	32	50	35	50	35
25	37	30	59	26	61	24	66	33	68	46	85	65	80	61	77	44	81	56	59	37	52	30	44	24
26	53	19	46	33	68	34	71	34	75	55	84	62	80	49	78	47	81	55	65	43	52	29	46	30
27	45	35	57	36	62	31	80	38	78	47	83	62	83	58	82	52	76	53	66	24	46	33	49	33
28	52	32	53	38	54	40	70	50	77	46	83	62	81	61	81	63	79	45	70	32	47	27	60	40
29	48	25	-----	-----	51	20	62	50	80	50	76	55	86	61	78	62	79	46	71	37	42	27	55	28
30	42	33	-----	-----	63	26	67	45	77	53	71	41	85	61	81	49	74	49	72	41	52	32	55	26
31	49	32	-----	-----	47	13	-----	-----	75	56	-----	-----	79	65	82	50	-----	-----	49	37	-----	-----	54	39
Average	45.5	26.7	44.2	22.8	56.6	29.8	64.4	36.2	71.9	44.8	81.3	53.3	81.4	57.8	81.4	58.2	77.5	52.9	66.2	36.6	52.1	30.4	55.7	22.6

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1924

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	50	24	47	30	58	26	62	30	64	45	72	50	77	57	84	65	90	60	59	36	67	38	34	18
2	28	23	47	31	53	31	40	24	66	30	73	50	73	55	82	53	79	60	70	31	68	32	31	12
3	46	27	62	31	58	29	57	22	72	33	70	46	67	55	77	53	72	54	72	34	69	32	43	17
4	37	15	62	29	62	29	55	29	70	50	70	45	73	58	80	61	76	44	73	19	70	38	40	30
5	31	5	59	41	56	43	50	36	81	40	70	40	70	58	88	56	71	47	76	38	67	34	41	31
6	36	-6	49	25	53	32	60	47	84	45	72	49	76	62	90	65	67	34	80	43	71	32	53	32
7	38	10	27	16	46	32	65	35	78	46	83	52	80	63	83	63	73	36	80	52	73	36	60	39
8	50	17	23	15	41	22	72	38	78	47	83	51	75	64	87	61	80	45	75	50	65	46	45	35
9	56	16	40	14	51	25	68	45	69	45	80	60	84	61	88	57	74	53	65	41	55	38	52	37
10	50	23	37	27	41	27	66	43	53	34	65	56	77	59	87	61	60	46	74	33	48	40	41	25
11	60	34	42	22	32	18	48	37	52	43	58	55	82	52	85	51	73	37	74	31	58	39	34	17
12	49	28	42	29	33	29	63	26	57	40	80	51	84	56	78	63	83	44	77	33	63	30	42	24
13	45	26	31	25	35	28	69	38	69	40	83	60	81	66	76	61	80	50	78	39	68	41	51	36
14	40	21	44	25	35	29	76	38	64	41	76	57	82	55	77	50	69	50	77	37	64	41	50	25
15	35	15	47	33	30	20	74	46	61	41	80	57	82	60	77	46	67	52	77	38	57	40	41	20
16	41	23	45	17	32	20	71	45	59	44	84	60	85	55	80	46	61	51	75	39	51	31	50	25
17	44	34	40	29	50	25	65	41	69	35	85	62	81	57	79	61	73	53	79	39	49	25	58	45
18	47	25	45	32	53	34	50	41	74	38	86	59	76	46	76	52	74	50	76	39	40	21	68	35
19	52	23	37	25	50	35	57	35	76	40	90	61	76	50	76	49	75	57	75	35	40	25	67	37
20	46	24	37	27	48	30	64	37	76	51	90	65	81	60	82	58	67	61	75	47	61	20	57	21
21	24	2	30	16	37	30	69	33	68	51	88	64	84	63	86	60	66	60	66	37	60	38	20	7
22	40	3	29	16	40	30	64	50	65	36	84	65	88	61	83	63	73	60	53	21	53	36	19	4
23	49	20	39	15	44	31	63	34	75	36	85	62	86	62	89	66	70	40	57	22	52	33	31	11
24	41	20	38	21	47	36	78	32	72	51	84	63	85	56	79	63	67	41	65	24	48	34	41	29
25	41	29	37	24	45	30	78	43	64	41	86	64	84	60	79	63	62	41	67	26	43	31	19	16
26	39	10	35	31	48	29	57	41	71	45	86	61	77	51	79	60	58	49	63	35	35	21	32	6
27	32	12	40	27	57	34	69	35	70	52	80	60	80	48	87	50	62	48	53	45	37	21	30	14
28	50	13	48	31	71	25	62	45	79	56	88	57	82	52	86	57	64	52	61	45	44	21	20	18
29	57	19	53	24	58	48	64	45	77	55	86	65	86	53	84	50	70	42	66	37	44	24	32	13
30	52	31			67	45	64	41	72	50	78	57	87	55	87	58	50	48	67	29	35	20	38	27
31	51	31			64	33			68	37			83	63	88	62			64	43			38	32
Average	43.7	19.2	41.9	25.1	48.2	30.1	63.3	37.7	69.4	43.3	79.8	56.8	80.1	57.2	82.3	57.5	70.6	48.6	69.7	37.1	55	31.9	41.7	24.1

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1925

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	34	24	43	25	47	30	44	28	48	35	89	49	80	55	76	53	85	59	64	54	44	28	47	21
2	34	25	46	34	35	20	47	38	55	34	91	50	90	58	81	47	86	55	58	53	49	34	46	30
3	40	32	40	35	38	6	60	23	58	31	92	55	88	62	84	48	90	58	75	53	52	42	48	34
4	38	25	48	29	45	17	58	27	58	33	92	55	89	66	78	58	93	63	75	56	46	33	62	30
5	40	25	54	23	45	31	52	35	58	41	93	56	91	64	83	57	93.5	52	78	53	50	38	57	43
6	43	16	58	22	56	26	58	30	60	30	85	59	89	63	85	55	90	58	67	42	56	41	46	26
7	43	32	60	29	62	30	66	19	59	32	85	54	90	64	89	52	91	63	68	52	52	42	49	26
8	44	25	69	27	65	30	71	28	61	30	87	60	88	65	92	53	87	68	68	51	61	38	55	30
9	37	27	59	39	67	40	66	40	61	38	86	59	91	64	88	65	92	58	63	53	43	24	47	33
10	37	27	58	43	68	37	61	45	72	43	86	59	90	65	94	56	90	60	64	32	52	22	46	36
11	33	30	53	39	73	36	66	39	72	53	84	51	89	64	93.5	60	94	59	58	29	63	24	49	30
12	31	23	29	18	73	47	70	47	60	53	78.5	46	85	68	91	65	94	61	63	42	61	41	50	37
13	26	25	41	16	58	40	74	34	60	49	76	51	88	65	94	64	84	64	64	52	54	43	55	38
14	30	19	42	23	61	37	78	34	57	51	88	63	88	58	89	64	86	62	58	49	59	45	51	42
15	36	11	48	30	45	28	75	47	72	41	89.5	62	84	61	87	52	86	64	70	51	62	32	43	28
16	38	26	48	30	45	19	66	46	76	43	83	66	89	60	85	61	78	68	71	52	57	32	43	31
17	41	28	47	39	57	37	63	41	72	59	85	63	86	62	88	50	81	53	71	60	39	29	33	28
18	39	36	45	24	63	31	63	41	66	49	90	62	78	50	89	52	86	49	63	49	56	19	37	21
19	39	25	50	25	63	51	72	50	69	44	83	66	78	45	92	63	87	61	56	44	57	30	40	19
20	39	36	61	26	53	33	70	55	76	38	85	58	82	50	92	59	92	59	45	32	49	33	43	31
21	41	25	59	31	67	25	54	34	71	46	87	56	85	59	78	62	83	65	48	31	54	29	45	32
22	49	27	58	29	60	33	58	42	83	51	89	58	83	68	76	46	78	58	44	34	56	24	48	32
23	26	17	58	45	59	25	80	43	80	52	84	60	83	58	75	48	63	50	49	23	43	25	33	18
24	42	14	50	40	63	28	87	50	69	55	67	60	85	58	78	45	76	58	50	35	38	17	37	17
25	44	24	58	30	64	35	89	52	52	40	82	63	86	61	83	45	78	55	60	45	54	22	38	29
26	52	30	40	29	66	35	70	52	51	33	80	59	87	65	88	43	70	52	59	34	47	28	32	17
27	52	27	35	16	43	41	75	56	62	27	85	53	85	63	89	53	80	55	54	33	58	28	19	2
28	28	4	40	13	41	31	65	41	70	34	85	59	85	55	85	60	81	57	59	24	47	32	19	−2
29	32	15	----	----	36	32	45	41	70	44	84	57	80	49	78	54	80	51	51	19	36	18	29	7
30	31	15	----	----	39	28	46	30	78	47	81	60	81	48	87	49	73	57	58	30	40	19	29	16
31	42	18	----	----	43	33	----	----	80	45	----	----	79	64	90	51	----	----	58	40	----	----	31	17
Average	38.9	23.5	49.8	29.2	54.8	31.3	64.6	39.6	65.6	42.1	85	57.4	85.5	59.6	85.7	54.3	84.2	57.6	65.5	42.1	57.1	34	41.8	26.8

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1926

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	52	22	42	33	49	27	48	31	85	42	77	56	90	56	86	66	83	52	71	59	57	27	48	26
2	49	32	52	31	42	21	59	34	85	42	80	46	92	61	89	64	83	62	73	60	46	31	40	22
3	41	16	46	31	25	12	64	39	70	53	81	56	93	60	87	64	80	65	84	61	49	19	48	30
4	44	35	36	31	30	12	54	29	65	37	79	50	85	61	87	66	71	62	85	57	53	22	54	31
5	59	38	33	25	34	17	61	26	72	29	55	48	85	66	88	65	85	65	82	57	44	34	50	26
6	50	40	43	16	48	15	65	36	77	36	73	45	85	65	89.5	60	85	64	71	53	59	22	48	23
7	41	27	42	32	58	32	70	31	85	42	78	52	83	65	88	63	84	65	57	43	61	22	39	14
8	31	19	50	27	38	24	70	54	86	48	84	47	87	55	83	55	79	64	63	31	54	31	48	27
9	30	18	43	27	35	17	64	38	80	55	81	48	86	61	87	51	85	62	68	35	65	50	46	35
10	25	16	36	19	49	29	56	33	78	52	82	42	90	67	93	60	84	62	71	43	59	29	50	35
11	38	4	24	11	45	31	68	47	72	43	86	43	70	62	96	62	77	52	64	53	36	23	45	34
12	28	25	44	13	37	32	52	34	69	47	90	54	81	44	95.5	63	83	50	72	51	46	14	38	23
13	33	9	59	33	35	18	40	30	71	39	82	61	79	54	94.5	65	88	54	69	53	49	23	60	33
14	30	12	61	44	33	12	62	35	70	42	90	58	75	52	94	67	72	52	73	49	65	40	50	35
15	38	18	46	35	33	17	59	44	69	39	86	62	72	51	85	65	68	51	70	46	67	46	37	26
16	40	9	41	25	38	23	66	29	67	46	76	53	80	43	87	65	85	59	67	42	63	40	27	9
17	38	18	52	19	42	24	63	43	80	59	68	53	85	47	85	66	85	55	68	40	56	26	38	11
18	55	33	49	33	64	23	60	40	83	41	84	55	91	51	82	65	70	62	72	37	47	36	38	21
19	53	39	51	30	68	32	50	30	86	46	81	52	93	61	85	67	76	59	74	53	37	28	39	10
20	60	25	46	22	62	39	52	26	73	49	70	49	96	57	82	63	85	55	68	50	30	26	43	25
21	52	30	60	32	58	31	73	33	76	38	74	54	99	57	77	58	80	56	61	41	31	26	48	41
22	52	18	62	41	58	26	74	44	76	41	74	53	100	61	78	61	86	59	65	27	44	16	49	38
23	30	11	56	35	51	40	71	49	71	43	80	57	92.5	68	79	63	82	53	59	35	53	22	45	34
24	34	18	46	20	67	41	75	40	84	35	79	50	86	50	78	63	87	60	58	46	47	22	45	33
25	29	22	61	35	69	38	62	45	85	61	79	48	89	59	74	64	88	62	50	34	47	22	52	43
26	36	13	52	40	60	35	52	31	87	52	80	58	85	64	78	55	80	56	43	30	53	40	48	29
27	38	24	40	26	40	30	65	23	82	52	72	53	70	58	80	53	63	48	49	34	49	29	34	19
28	40	23	48	17	44	23	63	45	69	39	79	50	73	60	87	54	72	52	67	25	43	22	35	22
29	40	7	----	----	56	23	68	39	72	44	86	46	80.5	65	88	56	70	59	71	32	54	26	42	38
30	46	22	----	----	54	26	77	38	78	48	90	55	86	67	84	61	75	59	73	43	51	37	34	18
31	48	33	----	----	61	41	----	----	79	57	----	----	89	62	84	60	----	----	60	39	----	----	42	22
Average	41.3	21.8	47.1	27.9	47.7	26.1	62	36.5	76.8	45.6	79.2	51.8	85.4	58.6	85.5	61.6	79.5	57.8	67.3	42	55.5	28.8	43.9	26.9

READING OF MAXIMUM AND MINIMUM THERMOMETERS, 1927

Date	Jan. Max.	Jan. Min.	Feb. Max.	Feb. Min.	Mar. Max.	Mar. Min.	Apr. Max.	Apr. Min.	May Max.	May Min.	June Max.	June Min.
1	37	25	50	21	35	20	64	41	62	35	72	59
2	42	20	51	41	35	21	50	40	73	31	72	50
3	43	30	64	28	30	20	57	36	79	43	62	55
4	45	32	61	42	43	19	54	37	74	51	72	52
5	38	30	57	37	56	16	57	34	78	45	75	59
6	41	32	61	35	58	33	64	40	75	51	69	40
7	33	22	57	38	55	32	62	44	75	53	69	50
8	39	20	54	34	52	40	50	33	73	56	76	45
9	38	23	53	33	50	32	35	32	83	56	84	52
10	31	20	53	38	57	34	53	32	79	62	79	61
11	22	16	50	29	62	30	62	26	76	51	84	62
12	35	−1	55	32	60	48	70	30	69	45	85	60
13	38	14	50	36	66	48	64	49	67	40	84	61
14	45	31	62	35	61	49	59	41	66	45	80	62
15	31	9	57	41	68	30	59	44	60	41	70	47
16	32	1	66	29	78	34	68	41	52	41	71	47
17	42	16	71	40	76	38	77	49	65	44	68	53
18	40	32	69	41	74	42	73	49	75	47	60	49
19	50	29	63	31	78	47	77	54	85	50	73	49
20	60	34	36	26	78	43	82	52	84	55	79	52
21	68	43	37	25	70	50	76	53	81	60	75	58
22	70	38	47	25	61	32	66	37	83	59	82	65
23	63	45	61	38	39	29	51	27	81	53	81	62
24	61	40	61	36	36	31	50	26	83	59	81	58
25	52	38	57	30	54	27	58	28	82	60	86	51
26	49	30	43	29	60	34	68	37	71	51	85	62
27	36	11	37	24	57	34	74	50	70	46	76	43
28	37	14	35	25	50	24	69	35	67	47	85	48
29	58	33	----	----	52	24	81	45	60	49	90	52
30	50	34	----	----	57	31	71	46	82	55	92	60
31	46	33	----	----	57	41	----	----	80	52	----	----
Average	44.2	25.6	54.2	32.8	56.8	33.3	63.3	39.6	73.3	49.5	77.2	53.9

Date	July Max.	July Min.	Aug. Max.	Aug. Min.	Sept. Max.	Sept. Min.	Oct. Max.	Oct. Min.	Nov. Max.	Nov. Min.	Dec. Max.	Dec. Min.
1	91	63	81	68	78	53	88	53	69	39	60	38
2	87	62	79	58	81	54	82	52	74	41	41	30
3	81	62	76	59	86	58	71	57	66	36	36	30
4	79	51	78	57	87	56	72	52	45	35	33	28
5	78	49	80	59	79	60	73	41	41	27	42	31
6	85	53	83	52	80	57	81	41	40	26	49	22
7	86	63	87	55	88	52	79	47	42	23	50	30
8	76	58	87	62	80	60	73	59	40	32	53	25
9	67	52	78	64	80	57	64	53	56	35	25	7
10	79	56	75	60	81	60	70	35	55	36	44	10
11	80	55	73	57	82	62	68	39	73	44	53	19
12	89	56	81	62	79	53	60	54	65	42	54	44
13	87	61	86	55	83	50	58	39	54	25	71	47
14	84	61	86	60	88	62	56	35	57	31	64	52
15	88	61	79	64	89	60	65	28	61	46	53	36
16	86	61	81	51	90	67	68	31	64	48	45	26
17	83	65	81	62	87	61	61	41	64	45	34	18
18	83	62	80	66	89	58	42	38	45	28	33	22
19	80	64	77	57	76	62	46	38	37	27	29	14
20	82	55	72	57	73	41	62	39	46	19	22	11
21	81	57	74	57	69	43	64	51	58	22	27	19
22	81	62	75	59	63	36	73	52	65	28	40	20
23	78	62	84	62	64	32	78	41	70	38	35	20
24	78	54	81	55	70	33	74	46	66	40	43	15
25	83	58	68	50	71	34	72	38	55	39	40	12
26	82	62	68	52	76	44	70	35	64	25	40	10
27	85	58	64	51	80	44	71	36	69	37	49	11
28	87	57	69	50	75	51	68	35	69	37	54	16
29	88	57	71	48	78	55	78	34	66	42	59	38
30	83	62	79	44	82	54	71	42	65	40	55	34
31	78	63	79	52	----	----	68	50	----	----	59	35
Average	82.4	58.6	77.8	56.8	79.4	52.1	68.5	42.9	58	34.2	44.9	24.6

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1919 TO DECEMBER 31, 1919

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temperature	Lowest Temperature	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Cloudy Days	Number of Cloudy Days
January	35.5	46.6	24.4	22.2	64	0	64	4.85	2	West	18	3	10
February	35.9	46.2	25.6	20.6	58	16	42	3.91	3	West	9	1	18
March	45.2	57.9	32.6	25.3	69	45	44	3.30	0	West	12	10	9
April	50.9	65.0	36.8	28.2	83	20	63	3.26	0	West	10	8	12
May	60.8	73.6	48.0	25.6	86	34	52	4.84	0	N.W.	8	9	14
June	69.2	80.6	57.7	22.9	90	47	43	7.49	0	East	4	18	8
July	72.8	84.7	60.9	23.8	90	49	41	6.22	0	West	7	12	12
August	68.4	80.0	56.8	23.2	89	42	47	3.02	0	West	13	9	9
September	63.4	79.8	46.9	32.9	86	31	55	0.33	0	West	17	8	5
October	62.0	73.1	50.9	22.2	86	33	53	4.62	0	West	9	4	18
November	43.1	52.5	33.7	18.8	71	19	52	2.07	0	West	12	6	11
December	30.2	38.2	22.3	15.9	58	12	46	3.50	1	N.W.	12	4	15

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1920 TO DECEMBER 31, 1920

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temperature	Lowest Temperature	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Cloudy Days	Number of Cloudy Days
January	30.9	39.6	22.2	17.4	61	1	60	2.59	.5	N.W.	5	8	18
February	29.8	37.1	22.5	14.6	50	3	47	3.09	6	West	1	6	22
March	41.1	53.2	29.0	24.2	69	5	64	3.54	0	West	11	5	15
April	47.3	58.3	36.3	22.0	76	21	55	3.21	0	West	9	6	15
May	53.6	64.6	42.5	22.1	78	27	51	3.24	0	West	15	5	11
June	63.2	73.4	52.9	20.5	84	39	45	4.08	0	West	16	7	7
July	67.2	77.5	56.8	20.7	86	46	40	7.05	0	West	21	4	6
August	65.2	71.8	58.6	13.2	80	49	31	4.18	0	West	5	6	20
September	60.8	68.2	53.3	14.9	76	38	38	3.99	0	West	7	8	15
October	49.8	61.8	37.7	24.1	76	28	48	.04	0	West	22	3	6
November	41.2	51.4	31.1	20.3	70	9	61	2.43	Trace	West	10	17	3
December	35.4	43.7	27.0	16.7	61	15	46	2.90	Trace	West	9	9	13

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1921 TO DECEMBER 31, 1921

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temperature	Lowest Temperature	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Cloudy Days	Number of Cloudy Days
January	33.0	43.8	22.1	21.7	60	3	57	5.62	25.25	West	9	11	11
February	37.5	47.6	27.4	20.2	70	12	58	3.68	4.50	West	9	5	14
March	52.3	66.0	38.6	27.4	80	20	60	2.18	0.0	West	14	8	9
April	53.8	66.9	40.8	26.1	86	23	63	1.89	Trace	West	10	7	13
May	57.6	68.1	47.2	20.9	80	33	47	2.77	Trace	N.W.	6	3	22
June	68.0	77.2	58.7	18.5	88	43	45	3.49	0.0	West	6	17	7
July	70.2	78.2	62.2	16.0	85	49	36	4.95	0.0	West	11	12	8
August	67.2	76.2	58.1	18.1	85	44	41	3.19	0.0	West	11	9	11
September	68.2	78.5	58.0	20.5	87	50	37	3.99	0.0	West	12	9	9
October	51.8	66.7	36.8	29.9	82	26	56	3.06	0.0	West	15	8	7
November	45.4	56.7	34.0	22.7	72	18	54	4.00	Trace	West	10	7	18
December	37.6	47.9	27.3	20.6	65	16	49	1.87	.05	West	9	4	18

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1922 TO DECEMBER 31, 1922

January	31.9	41.4	22.4	19.0	56	9	47	2.71	10.00	West	8	5	18
February	39.2	48.9	29.6	19.3	69	10	59	4.12	7.60	West	4	6	18
March	45.4	56.7	34.2	22.5	74	22	52	5.51	.60	N.W.	10	6	15
April	54.9	67.9	41.9	26.0	83	26	57	1.61	Trace	West	10	15	5
May	61.0	73.3	48.8	24.5	81	36	45	5.46	0.0	West	10	11	10
June	69.6	80.7	58.6	22.1	89	43	46	3.55	0.0	S.W.	8	14	8
July	71.8	82.5	61.0	21.5	89	53	36	5.83	0.0	West	8	18	5
August	67.8	79.1	56.5	22.6	85	42	43	2.84	0.0	West	11	10	10
September	65.0	79.9	50.0	29.9	88	37	51	2.80	0.0	West	15	9	6
October	54.9	69.5	40.3	29.2	86	25	61	2.89	0.0	N.W.	17	6	8
November	43.8	55.5	32.1	23.4	68	15	53	.65	1	N.W.	13	5	12
December	39.3	49.1	29.5	19.6	66	14	52	5.02	Trace	West	9	3	19

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1923 TO DECEMBER 31, 1923

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temperature	Lowest Temperature	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Clear Days	Number of Cloudy Days
January	36.1	45.5	26.7	19.1	54	14	40	3.39	10.3	N.W.	7	6	18
February	33.5	44.2	22.8	22.8	64	5	59	4.17	10.8	N.W.	10	5	13
March	43	56.6	29.8	26.8	74	11	63	4.34	Trace	N.W.	10	10	11
April	50	64.4	36.2	28.3	80	10	70	2.28	Trace	West	17	5	8
May	58	71.9	44.8	27	81	29	52	2.41	0.0	West	4	9	18
June	67.3	81.3	53.3	25.9	89	41	48	6.43	0.0	West	11	6	13
July	69.1	81.4	57.8	23.6	88	49	39	4.98	0.0	West	13	6	12
August	69.5	81.4	58.2	23.5	89	42	47	3.04	0.0	West	11	4	16
September	65	77.5	52.9	24.5	87	40	47	1.9	0.0	West	12	6	12
October	50.4	66.2	36.6	29.5	82	21	61	2.07	0.0	N.W.	16	8	12
November	41.2	52.1	30.4	21.7	65	21	44	3.18	Trace	West	9	8	18
December	38.6	55.7	22.6	22.6	66	11	55	3.82	1.5	West	7	5	19

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1924 TO DECEMBER 31, 1924

January	31.4	43.7	19.2	24.7	60	-6	66	4.23	3	West	13	1	17
February	36.5	41.9	25.1	16.7	62	15	47	2.28	17	N.W.	6	18	5
March	39.1	48.2	30.1	18.4	71	18	53	4.32	17.4	N.W.	8	6	17
April	50.5	63.3	37.7	25.9	78	22	56	3.71	Trace	N.W.	10	7	13
May	56.3	69.4	43.3	25.9	84	30	54	6.04	0.0	West	7	8	16
June	68.1	79.8	56.8	23.3	90	40	50	2.56	0.0	West	8	13	14
July	68	80.1	57.2	22.9	88	46	42	5.98	0.0	West	12	4	15
August	69.5	82.3	57.5	26	90	46	44	6.49	0.0	West	13	8	10
September	59	70.6	48.6	21.8	90	34	56	5.75	0.0	N.W.	11	2	17
October	53	69.7	37.1	32.9	80	21	59	1.68	0.0	West	22	4	5
November	43.4	55	31.9	23.4	71	20	51	2.21	1.2	West	12	2	16
December	32.9	41.7	24.1	14.5	68	4	64	3.82	Trace	N.W.	12	4	15

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1925 TO DECEMBER 31, 1925

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temperature	Lowest Temperature	Monthly Range	Precipitation in Inches	Snow in Inches	Prevailing Winds	Number of Clear Days	Number of Partly Clear Days	Number of Cloudy Days
January	31.2	38.9	23.5	14.6	52	4	48	3.97	18.2	West	18	0	13
February	38.5	49.8	29.2	20.5	69	13	56	1.61	5.8	N.W.	9	2	17
March	43.5	54.8	31.3	23.5	73	6	67	.94	2.4	N.W.	12	11	8
April	52.1	64.6	39.6	24.6	89	19	70	2.60	Trace	West	15	3	12
May	53.8	65.6	42.1	23.5	83	27	56	1.43	0.0	West	12	6	13
June	71.2	85	57.4	27.8	93	46	47	2.60	0.0	West	16	9	5
July	72.5	85.5	59.6	25.9	91	45	46	2.49	0.0	West	14	10	7
August	70	85.7	54.3	31.7	94	43	51	2.07	0.0	West	19	7	5
September	70.4	84.2	57.6	28.5	94	49	45	2.68	0.0	West	15	5	10
October	53.8	65.5	42.1	18.7	75	19	57	4.38	6.8	West	7	3	21
November	45.5	57.1	34	20.7	63	17	46	1.75	Trace	N.W.	14	5	16
December	34.3	41.8	26.8	16	62	−2	64	1.28	1.2	N.W.	15	5	11

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1926 TO DECEMBER 31, 1926

January	31.5	41.3	21.8	18.9	60	4	56	4.26	7.9	West	11	3	17
February	37.5	47.1	27.9	19	62	11	51	2.97	7.4	West	8	3	17
March	36.9	47.7	26.1	21.5	69	12	57	2.88	9.8	N.W.	11	5	15
April	49.2	62	36.5	25.5	77	23	54	2.12	Trace	West	12	3	15
May	60.2	76.8	45.6	31.8	87	29	58	1.29	0.0	West	16	6	9
June	65.5	79.2	51.8	27.4	90	42	48	1.88	0.0	West	10	6	14
July	72	85.4	58.6	26.5	100	43	57	4.06	0.0	West	16	3	12
August	73.5	85.5	61.6	23.5	96	51	45	3.92	0.0	West	13	9	9
September	68.6	79.5	57.8	21.6	88	48	40	2.28	0.0	East	11	3	16
October	54.6	67.3	42	22.7	85	25	60	4.25	Trace	West	11	4	16
November	41.9	55.5	28.3	22.1	67	14	53	2.46	Trace	N.W.	10	2	18
December	35.4	48.9	26.9	17	60	9	51	6.62	1.4	N.W.	7	4	20

TABLE SHOWING METEOROLOGICAL DATA JANUARY 1, 1927 TO DECEMBER 31, 1927

	Mean Temp. for Month	Mean Max. Temp. for Month	Mean Min. Temp. for Month	Average Daily Range	Highest Temp-erature	Lowest Temp-erature	Monthly Range	Precipita-tion in Inches	Snow in Inches	Prevail-ing Winds	Num-ber of Clear Days	Num-ber of Partly Clear Days	Num-ber of Cloudy Days
January	34.9	44.2	25.6	18.6	70	-1	71	1.32	2.8	West	7	2	22
February	46.5	54.2	32.8	21.4	71	24	47	4.63	4.9	West	8	4	16
March	46.05	56.8	33.3	23.4	78	16	62	1.21	3.3	West	11	8	12
April	50.45	63.3	39.6	23.7	82	26	56	6.41	Trace	West	6	6	18
May	61.4	73.3	49.5	24.4	85	31	54	2.95	0.0	West	6	9	16
June	65.5	77.2	53.9	23.2	92	40	52	1.85	0.0	West	8	8	14
July	70.5	82.4	58.6	28.8	91	49	42	6.67	0.0	West	17	6	8
August	67.3	77.8	56.8	21	87	44	43	4.08	0.0	N.W.	11	4	16
September	65.7	79.4	54.1	27.3	90	32	58	2.37	0.0	N.W.	21	4	5
October	55.6	68.5	42.9	25.6	88	28	60	4.14	0.0	East	22	8	6
November	46.2	58	34.2	23.6	74	19	55	2.66	.5	West	11	6	13
December	34.7	44.9	24.6	20.2	71	7	64	6.11	17.5	N.W.	16	1	14

ANNUAL REPORT

OF THE

Virginia Polytechnic Institute

Agricultural Experiment Station

FOR THE PERIOD JULY 1, 1927, TO JUNE 30, 1931

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

ORGANIZATION OF THE VIRGINIA AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

THE EXECUTIVE COMMITTEE OF THE BOARD OF VISITORS OF THE VIRGINIA POLYTECHNIC INSTITUTE

ROBT. S. MOSS, *Chairman* .... *Burke's Garden, Tazewell County*
ALLEN T. ESKRIDGE .... *Pulaski, Pulaski County*
JAS. P. WOODS .... *Roanoke, Roanoke County*
ROBT. A. RUSSELL .... *Rustburg, Campbell County*
J. A. BURRUSS, *ex officio* .... *Blacksburg, Montgomery County*

STATION STAFF

J. A. BURRUSS, A.M., PH.D. .... *President*
A. W. DRINKARD, JR., PH.D. .... *Director*
W. B. ELLETT, PH.D. .... *Chemist*
W. J. SCHOENE, PH.D. .... *Entomologist*
T. B. HUTCHESON, M.S. .... *Agronomist*
C. W. HOLDAWAY, M.S. .... *Dairy Husbandman*
W. D. SAUNDERS .... *Milk Investigations*
H. N. YOUNG, PH.D. .... *Agricultural Economist*
J. J. VERNON, M.S. .... *Agricultural Economist*
W. E. GARNETT, PH.D. .... *Rural Sociologist*
ILENA M. BAILEY, B.S. .... *Home Economist*
S. A. WINGARD, PH.D. .... *Plant Pathologist*
I. D. WILSON, D.V.M., PH.D. .... *Zoologist and Animal Pathologist*
R. E. HUNT, M.S. .... *Animal Husbandman*
B. L. HUMMEL, B.S. .... *Rural Sociologist*
W. S. HOUGH, PH.D. .... *Entomologist*
G. W. PATTESON, B.S. .... *Agronomist*
H. H. HILL, M.S. .... *Associate Chemist*
N. A. PETTINGER, PH.D. .... *Associate Agronomist*
F. W. HOFMANN, PH.D. .... *Associate Horticulturist*
G. W. UNDERHILL, M.S. .... *Associate Entomologist*
J. F. EHEART, M.S. .... *Assistant Chemist*
R. A. BALLINGER, PH.D. .... *Associate Agricultural Economist*
M. S. KIPPS, M.S. .... *Assistant Agronomist*
P. B. POTTER, B.S., A.E. .... *Associate Agricultural Engineer*
R. C. MOORE, B.S. .... *Assistant Horticulturist*
G. M. SHEAR, PH.D. .... *Assistant Plant Physiologist*
L. E. STARR, D.V.M., M.SC. .... *Assistant Animal Pathologist*
E. P. JOHNSON, D.V.M., M.S. .... *Assistant Animal Pathologist*
R. L. BRYANT, M.S., PH.D. .... *Assistant Poultry Husbandman*
A. D. PRATT, M.S. .... *Assistant Dairy Husbandman*
J. W. SJOGREN, M.S. .... *Assistant Agricultural Engineer*
R. H. HURT, B.S. .... *Assistant Plant Pathologist*
L. R. CAGLE, B.S.A. .... *Assistant Entomologist*
J. L. MAXTON, M.S. .... *Assistant Agricultural Economist*
A. M. WOODSIDE, M.S. .... *Assistant Entomologist*
C. J. BLAIR, JR., B.S. .... *Assistant Agricultural Economist*
R. G. HENDERSON, M.S. .... *Assistant Plant Pathologist*
A. B. GROVES, M.S. .... *Assistant Plant Pathologist*
N. A. EATON, JR., M.S. .... *Assistant Entomologist*
P. L. FLETCHER, M.S. .... *Assistant Agricultural Economist*
R. C. TALBOT, B.S. .... *Assistant Agricultural Economist*
E. SHULKCUM, M.S. .... *Assistant Agronomist*
A. C. SEYMOUR, M.S.A. .... *Assistant Rural Sociologist*
C. I. WADE .... *Treasurer*
R. R. SWOPE .... *Executive Clerk*

COUNTY EXPERIMENT STATIONS

T. B. HUTCHESON, M.S. .... *Supervisor County Experiment Stations*
W. W. GREEN (Bowling Green) .... *Superintendent Caroline Station*
B. G. ANDERSON, B.S. (Appomattox) .... *Superintendent Appomattox Station*
R. P. COCKE (Williamsburg) .... *Superintendent James City Station*
P. T. GISH, M.S. (Fishersville) .... *Superintendent Augusta Station*
T. L. COPLEY, B.S. (Chatham) .... *Superintendent Pittsylvania Station*
H. C. MARSHALL (Charlotte C. H.) .... *Superintendent Charlotte Station*
E. T. BATTEN, B.S. (Holland) .... *Superintendent Nansemond Station*
W. R. PERKINS, B.S. (Glade Spring) .... *Superintendent Washington Station*

Organization list corrected to September, 1931.

BULLETINS AND REPORTS ARE MAILED FREE TO ALL RESIDENTS OF THE STATE WHO APPLY FOR THEM

LETTERS OF TRANSMITTAL

To His Excellency, Governor John Garland Pollard:

Sir: In accordance with the Federal laws approved March 2, 1887, March 20, 1906 and February 24, 1925, I transmit for your consideration this report of the Virginia Agricultural Experiment Station for the period ending June 30, 1931. It includes a brief statement of the work completed or in progress, and the principal changes which have occurred since the issuance of the last report.

Respectfully submitted,

A. W. Drinkard, Jr., *Director*

September 1, 1931.

To President Julian A. Burruss,
Virginia Polytechnic Institute.

Sir: I have the honor to transmit to you the report of the Virginia Agricultural Experiment Station covering four fiscal years beginning July 1, 1927, and ending June 30, 1931.

Respectfully submitted,

A. W. Drinkard, Jr., *Director*

September 1, 1931.

CONTENTS

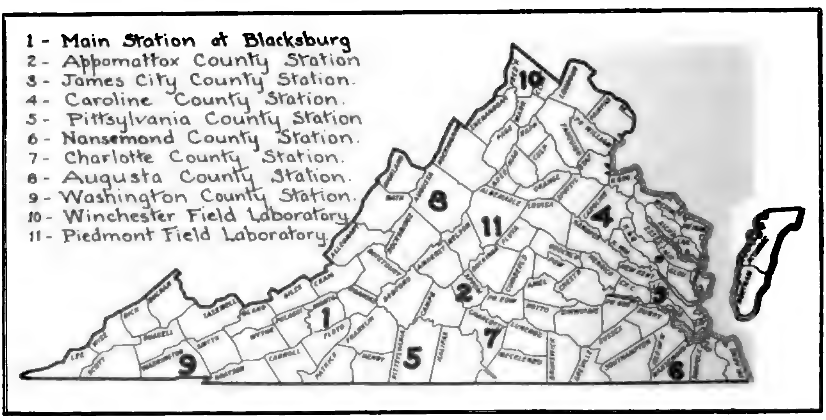


Fig. 1.—Showing on an outline map of Virginia the situation of the several centers of activity of the Agricultural Experiment Station

Annual Report of the Virginia Agricultural Experiment Station

By A. W. Drinkard, Jr., *Director*

The station has a special field of service in the promotion of agriculture through experiments, investigations and research designed to solve farming problems. This service affects not only farmers, but its benefits are also extended to all of the people in the state. When the results of the station's work show how to perform farming operations more efficiently the benefits are shared by all consumers of farm products.

THE CURRENT PROGRAM OF WORK

The activities of the station are organized in projects. Each project represents a separate line of inquiry and involves at least one, and sometimes several distinct farming problems. The object of the inquiry is to find a solution for the problem or problems involved. The station is now working on 130 separate projects.

A large group of projects deals with farm crops, such as the adaptation of varieties of the important farm crops to the different regions and to the different soil types in the state; the kinds and amounts of fertilizers required for economical production of crops; the improvement and maintenance of soil fertility through liming, rotations, soiling crops and fertilizer applications; chemical aspects of soils and plant nutrition; improvement of varieties of crops by breeding and selection of promising strains; grasses and other plants for better pastures; experiments and investigations dealing with methods for controlling diseases and pests of farm crops; and engineering features of certain farm machinery for cultivating and harvesting farm crops.

Another group of projects is designed to aid orchardists in the state, and among these may be mentioned fertilizer applications to increase fruiting of apple and peach trees; cultural practices and cover crops for orchards; comparison of methods for pruning fruit trees; a study of varieties of apple, peach, grape and other fruits as to their value for commercial and home orchards; methods for controlling insect pests of the orchard, including codling moth, curculio, leaf roller, leafhopper, woolly apple aphis and oriental fruit moth; methods for controlling diseases in the orchard, such as apple scab, bitter rot, blotch, brown rot, peach scab, rootrot and many other diseases; spraying machinery and developing better spraying materials.

Edition of 2,000 copies.

Problems dealing with livestock on the farm are being investigated. Numerous projects bearing on this subject are under way, among which the most important are, the protein and energy requirements for dairy cows; a comparison of different feeds as to their relative value in furnishing protein for milk production; using by-products for feeding purposes; supplemental feeds for beef cattle on bluegrass pasture; how to increase the carrying capacity of pastures; the management of the beef cow herd; pastures for hogs; methods for controlling diseases of livestock, such as the pullorum disease in poultry, the abortion disease in cattle, coccidiosis of cattle, and other diseases. Workers at the station are comparing peanut meal with meat scrap as a source of protein in the ration for chicks. The making of cheese from milk of high acid content is also being studied.

Still another group of projects deals with the economic and social problems of farming, and among these the most important are, farm taxation; tne assessment of farm real estate; economics of the management of the apple orchard; costs and profits of potato growing; costs of marketing livestock and wool; market distribution of Virginia dairy products; marketing tobacco; attitudes of rural people toward organizations; community development trends; and case studies in rural community development.

Several projects deal with problems of the homemaker, including the cooking quality and palatability of soft pork; content, adequacy and conditioning factors of rural family living; reliability of oven regulators; and home laundering.

When one project is completed another is taken up in the order of relative importance, so that the resources of the station may be used in the most effective way to aid the farmers in the state.

CONTRIBUTIONS TOWARD PROMOTION OF AGRICULTURE

Not every project undertaken by members of the station staff yields highly significant results, although every investigation which is thoroughly and conscientiously carried out has its value either in pointing the way to improved farm practices or in advancing the sciences underlying farming. A number of important contributions have been made by members of the station staff, some of which will be briefly discussed in the paragraphs which follow.

Control of Cedar Rust Disease of Apples.—The disease of apple commonly known as cedar rust for a time threatened the commercial apple orchards in several important fruit growing regions in Virginia. Investigations at this station showed that spraying could not be depended upon for relief from this disease, and that the only effective control was the eradication of red cedar trees from the vicinity of apple orchards. The station furnished the scientific facts on which the cedar rust law was based. Losses from cedar rust are now

largely avoided by the eradication of red cedar trees in the vicinity of apple orchards.

Diseases of Tobacco.—Fifteen years ago wildfire and angular leaf spot appeared in tobacco fields of Virginia in very destructive proportions, some farmers losing one-third to one-half of their crops because of injury by these diseases. The station started investigations and experiments on these diseases in 1917, proved that the diseases were caused by bacterial organisms and that they were disseminated in the seed. Control measures consisting of seed disinfection and plant bed sanitation were worked out and when these measures are properly applied they give a large measure of relief, and enable farmers to avoid serious losses from these diseases.

Improving Varieties of Wheat.—In 1910 two varieties of wheat were selected because of certain desirable characteristics, and they were propagated and finally distributed to farmers in Virginia. One of these wheat selections was named V. P. I. No. 131. It came from a head of wheat on a promising plant in the variety Fulcaster, which was at that time the leading variety of bearded wheat for this region. In a test extending over 14 years, V. P. I. No. 131 yielded 9 per cent more wheat than Fulcaster. Another selection was made from the Poole variety, and was named V. P. I. No. 112. This is a beardless variety of wheat. In a test extending over 14 years, V. P. I. No. 112 yielded 18 per cent more wheat than the Fultz variety.

At the present time 25 to 50 per cent of all the wheat grown in this state is either V. P. I. No. 131 or V. P. I. No. 112. In view of the larger yields secured from these new varieties of wheat it is apparent that their use on farms in Virginia increases in a significant way returns secured from the land devoted to the growing of wheat.

Fertilizer Experiments.—One of the first projects undertaken after this station was founded was a study of commercial fertilizers, and their relation to crop production. Numerous contributions have been made toward more scientific use of fertilizers. Both farmers and manufacturers of fertilizers make constant use of station data on this subject. At the present time commercial fertilizers are used extensively in Virginia, and the efficiency in the use of commercial fertilizers has been substantially increased by the station's experiments on this problem.

Pullorum Disease of Fowls.—Six years ago this station began investigations looking toward an effective control for bacillary white diarrhea (the pullorum disease of fowls). A rapid method for testing the blood of fowls was developed, and it was learned that the blood testing could be done at the farm and at about one-half the cost of the old method. It was shown that removal from the flocks of infected birds was a practical means for controlling the disease, and thus a serious loss to poultrymen was avoided.

Spray Service for Orchardists.—It is now generally recognized by orchardists that the proper timing of spray applications, coupled with thoroughness in spraying, is essential in the control of insect pests and diseases. The spray service furnished orchardists by the V. P. I. Agricultural Extension Division is based on the findings of the station workers with respect to the life history and habits of the several insect pests and diseases of fruit trees. These facts have been accumulated through years of intensive research; but past history is not a sufficient basis for the proper timing of sprays. Orchardists must know how current weather conditions are influencing the development and feeding habits of the enemies of the orchard. Hence, the station has placed entomologists and plant pathologists in the fruit growing sections at the field laboratories, who keep in touch with the developments of orchard pests; they supply the advice upon which spray practice may be safely based. Investigations concerning equipment for spraying brought to light important facts as to pressure in the spray pump, kind and arrangement of spray nozzles to give more efficient and economic results in spraying. The value of this work is indicated by the very general adoption of these methods by fruit growers in Virginia, and in many other states.

Poisonous Plants in Pastures.—Some years ago the station, in cooperation with the U. S. Department of Agriculture, investigated a problem of poisoning of cattle reported to us by raisers of beef cattle in southwestern Virginia. The farmers suspected larkspur as the cause of the trouble. Investigation showed that larkspur and two other poisonous weeds, known as dutchman's breeches and squirrel corn, were poisonous to cattle. Feeding trials with these plants were made under controlled conditions, and they demonstrated that larkspur was much less toxic to cattle than the other two weeds mentioned. Chemical investigations discovered the alkaloid constituents in these plants responsible for the poisoning. This investigation opened ways by which cattle farmers may take steps to avoid losses from this source.

Feeding Dairy Cows.—Experiments extending over a period of 20 years, undertaken to determine the protein and energy requirements for milk production, have shown that the feeding practices followed by a majority of farmers resulted in the waste of 20 to 25 per cent of the actual value of the feeds consumed by the cows because of improper balancing of the rations. Proper methods for balancing the rations were pointed out. This investigation has shown also that peanut meal and soybean meal, by-products of crops widely produced in Virginia, compare favorably with cottonseed meal as sources of protein for the ration of dairy cows. Another phase of this investigation showed that Hevea rubber seed meal was a good source of protein for the ration of the dairy cow.

Farm Economics and Marketing.—The past decade has been rather a trying period for Virginia farmers as a whole, and the station has made an

earnest effort to serve the farmers effectively in the field usually spoken of as economics, or the business aspects of farming. Ten years ago the station was not conducting any investigations in this field, but at the present time our program of work in home economics, agricultural economics and rural sociology constitutes a very important part of our work. Investigations have been made and results published on the cost of producing tobacco, causes of profit or loss on tobacco farms, the farming situation in several regions of the state, systems of beef cattle farming, marketing milk, adjusting production to market requirements, taxation, stock share renting, systems of dairy farm management, and marketing woodland products. All of these studies brought out results which are helpful to farmers; moreover, our current program of work gives an important place to studies bearing on the business side of farming.

Rural Social Problems.—Questions concerning organizations and agencies which deal with rural social problems have come to be very important. Studies have been made and the results published on attitudes of farm people toward organizations, the relation of the rural church to community life, and the relation of young people's organizations to rural life. There is no doubt but that more knowledge of the principles underlying social relations will be exceedingly useful in helping to build the foundation for a better rural civilization.

New Uses for Farm and Industrial Products.—The station is striving to serve the state through finding means to make new uses of farm products whenever possible, and to make application of industrial products to new kinds of use on the farm, thereby widening the market for such products. Already several worthwhile contributions have come out of these efforts.

Feeding trials at the station showed that dried apple pomace compared favorably with dried beet pulp and corn silage as succulent feed for dairy cows. The relative values on the basis of digestible nutrients may be stated as follows: 1 ton of dried beet pulp is equivalent to 4 tons of corn silage; and 1 ton of dried apple pomace is equivalent to 3 tons of corn silage. These facts were recognized promptly by dairymen, and there arose a substantial demand for dried apple pomace, which heretofore was a waste product at the large vinegar plants in our state. This information proved helpful to both fruit growers and dairymen.

A firm at Norfolk was importing quantities of the seed of the Para rubber tree for the purpose of extracting the oil which is used in the paint industry, the pulp, which carries over 30 per cent of protein, being virtually a waste byproduct at the factory. Feeding trials showed that meal made from the cake after the oil is expressed from the rubber seed compared favorably with linseed meal as a source of protein in the dairy cow's ration. Thus a new use was found for an industrial waste product, and the dairymen were given one new source from which to choose their protein concentrates.

Extensive feeding trials with chicks showed that peanut meal could be substituted for at least 50 per cent of the meat scrap in the ration of chicks, and this investigation indicates a new method for using peanut meal, which will interest both poultrymen and the producers of peanuts.

In recent years workers at the station discovered that calcium sulphide is a very useful material for the control of diseases on the apple and peach. Anhydrous calcium sulphate, from which calcium sulphide is made by a process of roasting, is mined in Virginia and in many other places in this country. Since our original experiments were made on using calcium sulphide as a fungicide on apple and peach trees, this material has been tried out by station workers in a number of states with very favorable results, and there is reason to think that calcium sulphide will come to be one of the important materials for orchard spraying.

A member of the station staff discovered that lignin pitch, or sulphite waste from paper and pulp mills, can be used effectively in certain spray materials. Lignin pitch is available in powdered and liquid forms and may be substituted at less cost for calcium caseinate in the preparation of the cold-mix oil emulsions and in dry-mix lime-sulphur. There is a definite place for these materials in orchard spraying.

The Spray Residue Problem.—Due to the unprecedented drought of 1930 fruit growers in Virginia encountered a serious problem in connection with the presence of spray residue on the apples. In normal seasons the rainfall in this state is sufficient to wash the greater part of the spray materials from the apples before the apples are harvested. This year, however, there was little rain between the time the sprays wre applied in July and the time the apples were picked in September and October. Consequently, the amount of spray residue (particularly arsenic trioxide) on the fruit was above the tolerance for both domestic and foreign markets. Therefore, it was necessary to adopt measures for removing the spray residue from the fruit before it was marketed. Fruit growers in the West encountered this problem several years ago and stations in that region devised methods for the removal of the objectionable materials from the apples. In the summer of 1930 this station procured a fruit washing machine and installed it in an orchard in the Piedmont region where it was operated successfully throughout the season, in cooperation with local fruit growers. Home-made washers and various machines and devices for wiping the spray residue from the fruit were tried out. Members of the staff, including chemists, horticulturists, entomologists and plant pathologists cooperated effectively in aiding the fruit growers in this emergency. The division of chemistry and the division of markets of the State Department of Agriculture worked actively on this problem at the same time, and made many hundreds of analyses to determine the amount of arsenic present on samples of fruit from different orchards. As a result of these joint efforts, fruit

growers were supplied promptly with effective methods for removing the objectionable spray residue from their fruit. Our Bulletin No. 278 describes the experiments and gives conclusions as to methods for handling the spray residue problem. Thus a distinct service was rendered the fruit growers of Virginia in this emergency.

SOME PRESSING NEEDS

There have been frequent demands from groups of farmers for an expansion of the activities of the station in certain fields. These demands have come from fruit growers, poultrymen, dairymen, home makers, livestock farmers and a number of other groups of rural people who feel that the station service should be expanded along certain lines of investigation, and that entirely new lines of investigation should be taken up in several cases.

The station is now using to the limit the resources at its disposal. Provision should be made as soon as possible for additional members of the scientific staff to enable the station to take up new lines of investigation. There is need for scientific apparatus and equipment. Some of these needs are mentioned under the discussion of the progress and results of research in the several departments of the station.

Laboratory space and library space are far from adequate. The station needs a building of fire-proof construction to provide more adequate laboratories and to house the agricultural branch of the library. Such a building would cost about $100,000 and it would greatly increase the efficiency of the station's service to the state.

ADDITIONS TO EQUIPMENT

The facilities for research at the Winchester Field Laboratory were greatly improved. The Frederick County Fruit Growers Association, with contributions from a few fruit growers in nearby counties, generously donated $2,027.01 for the construction of the laboratory and insectary. Use of the land on which the laboratory is situated was granted by the Shenandoah Valley Vinegar Company. The laboratory building and insectary are shown in Figure 2. The laboratory building is a substantial frame structure 25 feet by 35 feet, containing two offices, two laboratory rooms, a dark-room for photographic work, and a basement 12 feet by 25 feet. There is water in the building and the building is heated by a furnace. The insectary is 12 feet by 35 feet, equipped with running water and shelving, and it is screened. There is a storeroom 7 feet by 10 feet at the end of the insectary (not shown in the picture). The station purchased equipment suitable for conducting research in entomology and plant pathology, including a motorized spraying outfit. The cost of the equipment at the Winchester Field Laboratory was approximately $2,000.00.

Fig. 2.—View of the Winchester Field Laboratory constructed in the fall of 1927

The cottage at the experiment station plats was improved in 1928 by the addition of two rooms at a cost of about $1,000.00.

In 1927, the three-inch water line was extended to the barns at the experiment station plats, as protection against fire, at a cost of $250.00. In the same year the greenhouses were repaired and an insectary was added to the eastern side of the head-house, with suitable shelving and screening, at a cost of $3,000.00. The insectary is 19 feet by 26 feet and is used for investigations in entomology. A view of the insectary is shown in Figure 3.

In the fiscal year 1927-1928, a cottage was constructed at the Augusta County station, costing $2,250.00, for use of the laborer at that station. The following year a 5-horse power motor was installed for pumping water and cutting feed, the buildings at this station were painted and the machinery shed was repaired, at a cost of $650.00.

In 1928, one of the greenhouses was improved to meet the needs of investigations in plant physiology, at a cost of $400.00. Also a small structure 25 feet by 32 feet (divided into three rooms) was built near the barns at the agronomy plats for storing seed and for a working laboratory in connection with the agronomy experiments, which cost $975.00.

In this period, four poultry colony houses were built for handling the fowls used in poultry disease investigations, at a cost of $320.00; and a colony

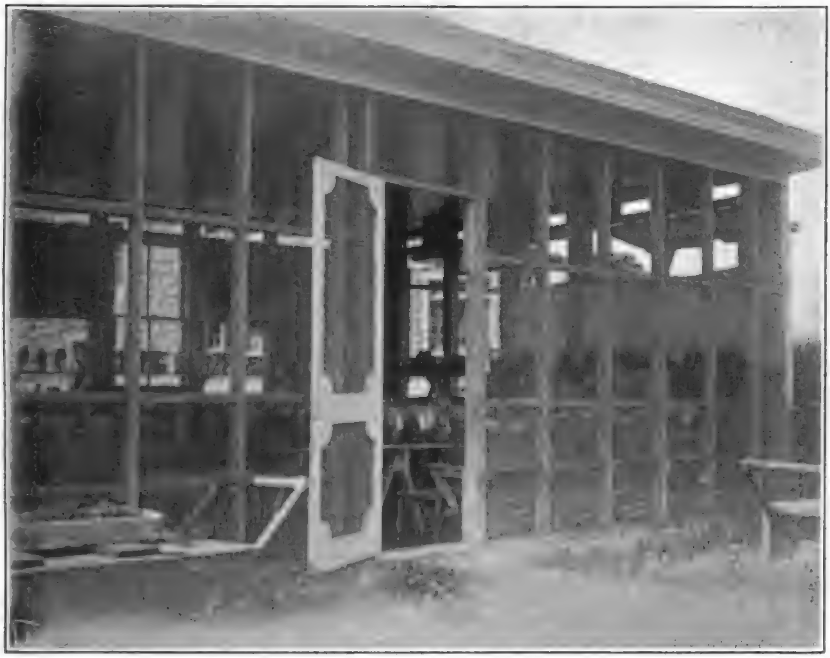


Fig. 3.—The insectary at Blacksburg, used for research on insect pests

brooder house was constructed for experiments in the poultry husbandry department, at a cost of $700.00.

In 1930, a herd of 40 grade Hereford heifers was purchased at a cost of $3,000.00 for an investigation of problems in the management of beef cows.

The Piedmont Field Laboratory at Charlottesville was constructed in 1930. The laboratory is a substantial structure 26 feet by 30 feet, with a full basement. The insectary is 12½ feet by 36 feet. These structures provide convenient facilities for experiments and investigations bearing upon insect pests and diseases of fruits. This laboratory was made possible through the generous donation of $2,500.00 for this purpose by fruit growers in this region; also by an appropriation from the General Assembly of Virginia to cover the remainder of the cost of these structures and necessary equipment for the laboratory. The cost of the structure was approximately $4,000.00 and of the equipment $2,500.00.

A laboratory for research in home economics was provided by partitioning one of the lecture rooms in the Agricultural Hall. The cost of the partition was $300.00 and the cost of the equipment, including electric stove, refrigerator, wiring, plumbing, etc., was $900.00. The laboratory is equipped for experiments on the cooking of meats and similar lines of research.

Fig. 4.—View of the Piedmont Field Laboratory

Scientific apparatus is purchased from time to time to provide for the needs of the station work in its several departments.

The agricultural branch library is being built up gradually by the accession of books, bulletins and scientific journals. About 1,000 volumes of bulletins and journals are bound each year in order to preserve valuable material and make it more accessible to members of the staff who must use the library constantly.

CHANGES IN THE STAFF

Appointments

Roy A. Ballinger, assistant agricultural economist, July 16, 1927.
Everett F. Davis, assistant plant physiologist, August 29, 1927.
N. A. Pettinger, associate agronomist, September 1, 1927.
R. R. Swope, executive clerk, September 6, 1927.
L. E. Starr, assistant animal pathologist, November 1, 1927.
Ilena M. Bailey, home economist, December 5, 1927.
Lewis D. Lasting, acting assistant chemist, October 1, 1828.
I. D. Wilson, zoologist and animal pathologist, October 1, 1928.
R. E. Hunt, animal husbandman, October 1, 1928.
Chas. J. Blair, Jr., assistant agricultural economist, January 1, 1929.
Robert G. Henderson, assistant plant pathologist, March 20, 1929.
Reece L. Bryant, assistant poultry husbandman, July 1, 1929.
B. L. Hummel, rural sociologist, July 1, 1929.
A. B. Groves, assistant plant pathologist, September 1, 1929.
Paul L. Fletcher, graduate assistant in agricultural economics, September 15, 1929.
C. C. Taylor, agricultural economist, March 1, 1930.
N. A. Eaton, Jr., assistant entomologist, March 27, 1930.
W. R. Perkins, superintendent Washington County station, April 1, 1930.
G. W. Patteson, agronomist, July 1, 1930.
Edward Shulkcum, assistant agronomist, July 1, 1930.
P. B. Potter, associate agricultural engineer, July 1, 1930.
G. M. Shear, assistant plant physiologist, July 1, 1930.
E. P. Johnson, assistant animal pathologist, September 1, 1930.
Robert A. Polson, acting assistant rural sociologist, September 1, 1930.
A. D. Pratt, assistant dairy husbandman, September 15, 1930.
John W. Sjogren, assistant agricultural engineer, October 1, 1930.

Resignations, Separations, and Transfers

T. K. WOLFE, agronomist, resigned September 1, 1927.

M. P. MILLER, acting assistant chemist, resigned September 1, 1927.

O. B. CORELL, executive clerk, resigned September 1, 1927.

HERMAN FARLEY, assistant animal pathologist, was transferred to V. P. I. testing laboratory, October 1, 1927.

ELLEN A. REYNOLDS, home economist, resigned October 7, 1927.

F. D. FROMME, plant pathologist, resigned June 30, 1928.

V. R. HILLMAN, assistant agricultural engineer, was transferred to full time college duties on July 31, 1928.

C. R. NOBLES, assistant animal husbandman, died August 13, 1928.

F. J. SCHNEIDERHAN, associate plant pathologist, resigned June 30, 1929.

H. L. PRICE, horticulturist, was transferred to full time duties in the college, July 1, 1929.

LEWIS D. LASTING, acting assistant chemist, resigned December 31, 1929.

O. P. STRAWN, superintendent Henry County station, resigned January 31, 1930.

EVERETT F. DAVIS, assistant plant physiologist, resigned June 30, 1930.

D. C. HEITSHU, assistant agricultural engineer, resigned July 31, 1930.

RUSSELL A. RUNNELLS, animal pathologist, resigned August 31, 1930.

C. C. TAYLOR, agricultural economist, resigned November 15, 1930.

Promotions and Leaves of Absence

S. A. WINGARD, from associate plant pathologist to plant pathologist, May 17, 1928.

G. W. UNDERHILL, from assistant entomologist to associate entomologist, May 17, 1928.

F. J. SCHNEIDERHAN, from assistant plant pathologist to associate plant pathologist, May 17, 1928.

ILENA M. BAILEY, home economist, was granted leave of absence August 1, 1928 to September 15, 1928 to pursue graduate study at the University of Chicago.

J. F. EHEART, assistant chemist, was granted leave of absence from October 1, 1928 to January 1, 1930 to pursue graduate study at Columbia University.

A. M. WOODSIDE, assistant entomologist, was granted leave of absence during the month of February, 1929 and from November 1 to December 20, 1930 to pursue graduate study at Ohio State University.

EVERETT F. DAVIS, assistant plant physiologist, was granted leave of absence for the fiscal year 1929-1930 to pursue graduate study at Johns Hopkins University.

M. S. KIPPS, assistant agronomist, was granted leave of absence from September 15, 1929 to June 23, 1930 to pursue graduate study at Michigan State College.

RUSSELL A. RUNNELLS, from associate animal pathologist to animal pathologist, April, 15 1930.

W. S. HOUGH, from associate entomologist to entomologist, June 10, 1930.

C. H. HAMILTON, assistant rural sociologist, was granted leave of absence from October 1, 1930 to June 1, 1931 to pursue graduate study at Harvard University.

PUBLICATIONS

Publications reporting the results of station work were issued on a number of subjects during the period of time covered by this report. The list which follows mentions the principal publications.

Bulletins

Nos.

259—A study of the biology and control of the red-banded leaf-roller. By W. S. Hough. 29 pages, 6 figures. December, 1927.

260—Orchard spraying and spray equipment. By W. S. Hough. 12 pages, 3 figures. February, 1928.

261—Life history of the codling moth in Virginia. By W. J. Schoene, W. S. Hough, L. A. Stearns, L. R. Cagle, C. R. Willey and A. M. Woodside. 56 pages, 7 figures. March, 1928.

262—The control of cereal smuts by seed treatment. By F. D. Fromme. 16 pages, 4 figures. June, 1928.

263—The market for milk in Richmond, Virginia. By J. J. Vernon and R. S. Kifer. 15 pages, 4 figures. June, 1928.

264—Life history and control of the pale-striped and banded flea beetles. By G. W. Underhill. 20 pages, 6 figures, 2 charts. June, 1928.

265—Bacillary white diarrhea (pullorum infection of the domestic fowl). By Russell A. Runnells. 27 pages, 3 graphs. March, 1929.

266—The adjustment of agricultural production to meet home market demands in the Clifton Forge-Covington trade area By J. J. Vernon, T. D. Johnson, and Wilbur O'Byrne. 30 pages 3 figures. April, 1929.

267—The role of the church in rural community life in Virginia. By Charles Horace Hamilton, and William Edward Garnett. 191 pages, 61 figures, bibliography. June, 1929.

268—Taxes on farm and urban real estate in Virginia. By Roy A. Ballinger and Whitney Coombs. 30 pages, 7 figures. September, 1929.

Nos.

269—Soil management experiments with the application of fertilizers in apple orchards. By F.W. HofMann. 35 pages. March, 1930.

270—Life history of the oriental fruit moth in Virginia. By LeRoy Cagle. 48 pages, 13 figures. May, 1930.

271—Stock share renting in Virginia. By Roy A. Ballinger. 54 pages, 5 figures, bibliography. May, 1930.

272—Systems of dairy farm management for the Richmond milk producing area. By J. L. Maxton, R. S. Kifer and J. J. Vernon. 95 pages, 21 figures. June, 1930.

273—The Negro church in rural Virginia. By C. Horace Hamilton and John M. Ellison. 40 pages, 7 figures, bibliography. June, 1930.

274—Young people's organizations in relation to rural life in Virginia (with special reference to 4-H clubs). By William Edward Garnett. 87 pages, 24 figures. June, 1930.

275—Marketing fluid milk in four Virginia cities. By J. L. Maxton and C. C. Taylor. 42 pages, 4 figures. December, 1930.

276—Marketing woodland products in Virginia. By J. Elton Lodewick. 69 pages, 23 figures. December, 1930.

277—The waste sulphite material of paper mills as an adjuvant to certain spray materials. By R. H. Hurt. 10 pages. February, 1931.

278—Removal of spray residue from apples. By W. S. Hough, R. H. Hurt, W. B. Ellett, J. F. Eheart, and A. B. Groves. 16 pages, 5 figures. June, 1931.

Technical Bulletins

Nos.

31—The Cicadellidae (Homoptera) of Virginia. By Louis A. Stearns. 21 pages, 1 figure. November, 1927.

32—The importance of properly balanced rations in trials to determine digestibility as shown in experiments with dried apple pomace. By C. W. Holdaway, W. B. Ellett, J. F. Eheart, and M. P. Miller. 18 pages. December, 1927.

33—*Erythroneura Hartii* (Gill.), an occasional leafhopper pest on the apple. By Louis A. Stearns. 15 pages, 5 plates, bibliography. January, 1928.

34—The black rootrot disease of apple. By F. D. Fromme. 52 pages, 20 figures. March, 1928.

35—Tests of tobacco fertilizers comparing nitrogen, phosphorus and potassium from different fertilizer sources. By T. B. Hutcheson and T. L. Copley. 10 pages. January, 1929.

36—Calcium sulphide for the control of apple and peach diseases. By R. H. Hurt and F. J. Schneiderhan. 15 pages, 2 figures. February, 1929.

Nos.

37—Historical study of prices received by producers of farm products in Virginia, 1801-1927. By Arthur G. Peterson. 218 pages, 46 figures, and 123 tables. March, 1929.

38—Methods of balancing rations for dairy cows in digestibility trials with corn meal. By C. W. Holdaway, W. B. Ellett and J. F. Eheart. 10 pages. May, 1929.

39—Studies on the ox warble flies, *Hypoderma lineatum* and *Hypoderma bovis*, with special reference to economic importance and control. By L. I. Case. 12 pages, 2 figures. September, 1929.

40—A study of hibernation of the corn earworm in Virginia. By W. J. Phillips and George W. Barber. 24 pages, 2 figures, 8 charts. November, 1929.

41—Feeding Hevea rubber seed meal for milk production. By W. B. Ellett, C. W. Holdaway, J. F. Eheart and L. D. Lasting. 12 pages. April, 1930.

42—A study of bovine coccidiosis. By Irl Donaker Wilson. 42 pages, 7 plates, 20 figures. May, 1931.

Contributions to Journals and Other Publications

Bailey, Ilena M., Research work in home economics at the agricultural experiment stations. The Virginia Teacher, Vol. 10, pages 89-92. 1929.

Ballinger, R. A., Stock share renting in Virginia. Social Science Abstracts, page 54. May, 1931.

Burmeister, Charles A. (with the collaboration of J. J. Vernon and C. R. Nobles), Economic factors affecting the beef-cattle industry of Virginia. U. S. Department of Agriculture Technical Bulletin No. 237. 66 pages, 8 figures, 21 tables. April, 1931.

Cagle, L. R., The oriental fruit moth. Proceedings 33rd Annual Meeting Virginia State Horticultural Society, pages 133-136. January, 1929.

Cagle, LeRoy, The plum curculio outbreak in Charlottesville-Crozet section of Virginia in 1929. Journal Economic Entomology, Vol. 23, pages 157-162. February, 1930.

Cagle, L. R., The oriental peach moth. Proceedings 35th Annual Meeting of the Virginia State Horticultural Society, pages 104-115. January, 1931.

Cagle, L. R., The oriental fruit moth. Virginia Fruit, Vol. 19, page 12. April, 1931.

Davis, E. F., The toxic principle of *Juglans nigra* as identified with synthetic juglone, and its toxic effects on tomato and alfalfa plants. American Journal of Botany, Vol. 15, page 620. December, 1928.

Drinkard, A. W., Jr., Lowering the cost of production of farm products. V. P. I. Extension Division News, Vol. 10, pages 1 and 4. December, 1927.

Drinkard, A. W., Jr., A discussion of the most important difficulties met with in research. Virginia Tech Engineer, Vol. 3, pages 15, 16 and 32. March, 1928.

Drinkard, A. W., Jr., Relationships and needs in rural sociology from the standpoint of research. Publication American Sociological Society, Vol. 24, pages 212-214. May, 1930.

Drinkard, A. W., Jr., The experiment station's research program for horticulture. Proceedings 35th Annual Meeting of the Virginia State Horticultural Society, pages 157-163. January, 1931.

Ellett, W. B. and H. H. Hill, Effect of lime materials on the outgo of sulphur from Hagerstown silt loam soil. Journal of Agricultural Research, Vol. 38, pages 697-711. June, 1929.

Fromme, F. D., Wingard, S. A., and Priode, C. N., Ringspot of tobacco; an infectious disease of unknown cause. Phytopathology, Vol. 17, pages 321-329. 1927.

Fromme, F. D., Black rootrot disease of apples. Proceedings 32nd Annual Meeting Virginia State Horticultural Society, pages 87-95. 1928.

Fromme, F. D., Studies of black rootrot of apple. Phytopathology, Vol. 18, page 145. 1928.

Garnett, W. E., Organizational situation in rural Virginia. Southern Planter, Vol. 88 (No. 21), pages 15-16. November, 1927.

Garnett, W. E., Farm incomes and standards of living. Southern Planter, Vol. 89 (No. 5), pages 30-31. March, 1928.

Groves, A. B., Natural fire-blight infections on *Spiraea Vanhouttei*. Phytopathology, Vol. 21, pages 89-91. January, 1931.

Hamilton, C. H., What the church is doing in behalf of rural living standards in Virginia. Bulletin of the V. P. I., Vol. 23, No. 3, pages 111-123. January, 1930.

Hamilton, C. Horace, Some factors affecting the size of rural groups in Virginia. American Journal of Sociology, Vol. 36, pages 423-434. November, 1930.

Hamilton, C. Horace, A statistical index of topography. Social Forces, Vol. 9, pages 204-205. December, 1930.

Henderson, R. G., Transmission of tobacco ring spot by seed of *Petunia*. Phytopathology, Vol. 21, pages 225-229. February, 1931.

Heitshu, D. C., The combine in Virginia. Present status of combine harvesting. Special supplement of Transactions of the American Society of Agricultural Engineers, pages 11 and 12. November, 1927.

Heitshu, D. C., Soybean harvesting methods in Virginia. Journal of the American Society of Agricultural Engineers, Vol. 9, pages 209-214, 9 figures. July, 1928.

Heitshu, D. C., The requirements of the general-purpose tractor. Agricultural Engineering, Vol. 10, pages 145-153. May, 1929.

Hill, H. H., Plant juice clarification for nitrate nitrogen determinations. Science, Vol. 71, page 540. May, 1930.

HofMann, Fred W., Profitable application of certain fertilizers to apple orchards in Hagerstown soil series. Proceedings American Society for Horticultural Science 1929, pages 153-157. February, 1930.

HofMann, Fred W., Effects of nitrogen, phosphoric acid, and potash applications on yields and circumference growth in ensembled data from cultivated apple orchards. Proceedings American Society for Horticultural Science 1929, pages 145-148. February, 1930.

HofMann, Fred W., Sources of nitrogen in orchard fertilization. Proceedings 35th Annual Meeting of the Virginia State Horticultural Society, pages 180-191. January, 1931.

HofMann, Fred W., Time of applying nitrogen to apple trees. Proceedings of the American Society for Horticultural Science for 1930, pages 19-22. February, 1931.
Hough, W. S., Practical points in the control of apple worms. Proceedings 32nd Meeting Virginia State Horticultural Society, pages 113-114. January, 1928.
Hough, W. S., Spraying equipment for orchards. Southern Planter, Vol. 89 (No. 4), pages 5 and 8. February, 1928.
Hough, W. S., Relative resistance to arsenical poisoning of two codling moth strains. Journal of Economic Entomology, Vol. 21, pages 325-329. April, 1928.
Hough, W. S., The delayed dormant spray. Proceedings 33rd Annual Meeting Virginia State Horticultural Society, pages 129-133. January, 1929.
Hough, W. S., Studies of the relative resistance to arsenical poisoning of different strains of codling-moth larvae. Journal of Agricultural Research, Vol. 38, pages 245-256. February, 1929.
Hough, W. S., Improving our spray equipment. The American Fruit Grower Magazine, Vol. 50, pages 6 and 26. March, 1930.
Hough, W. S., Recent developments in the control of spray injury. Proceedings of the Maryland Horticultural Society, pages 214-221. January, 1930.
Hough, W. S., Results of experiments to control spray injury on apples. Fruits and Gardens, pages 8-9. February, 1930.
Hough, W. S., Improved equipment for orchard spraying. Report of the 36th Annual Meeting of the Massachusetts Fruit Growers' Association, pages 108-117. January, 1930.
Hough, W. S., Results of experiments to control spray injury on apples. Proceedings of Virginia State Horticultural Society for 1929, pages 143-147.
Hough, W. S., Status of codling moth control in Virginia orchards. Proceedings 35th Meeting of the Virginia State Horticultural Society, pages 135-139. January, 1931.
Hough, W. S., Removal of leafhopper specking from apples. Journal of Economic Entomology, Vol. 24, page 327. February, 1931.
Hummel, B. L., Community organization in relation to higher standards of living. Bulletin of the V.P.I., Vol. 23, No. 3, pages 133-140. January, 1930.
Hummel, B. L., Looking ahead in rural organization. Publication American Sociological Society, Vol. 24, pages 173-197. May, 1930.
Hummel, B. L., Inter-community conflict. Publication of the American Sociological Society, Vol. 24, No. 4. November, 1930.
Hurt, R. H., New developments in spray materials. Proceedings Virginia State Horticultural Society for 1929, pages 158-169. December, 1929.
Hurt, R. H., Calcium monosulphide, a substitute for lime-sulphur or other standard sulphur combinations for summer spraying. Proceedings 34th Annual Meeting Virginia State Horticultural Society, pages 158-169. 1930.
Hurt, R. H., New spray materials for apples and peaches. Proceedings 35th Annual Meeting of the Virginia State Horticultural Society, pages 88-95. January, 1931.
Kipps, M. S., The production of seed potatoes in Southwest Virginia for eastern Virginia farmers. Proceedings of the Potato Association of America, Vol. 14, pages 52-56. December, 1927.
Johnson, E. P., Results of experiments with the use of pigeon-pox virus as cutaneous vaccine against fowl-pox. Journal of the American Veterinary Medical Association, Vol. 79 (New Series 32), pages 81-86. July, 1931.
Patteson, G. W., Know your soils for profitable crop production. The Loudoun-Fauquier Breeders' Magazine, Vol. 2, pages 17-18. 1931.
Patteson, G. W., Proper land utilization in northern Virginia. The Loudoun-Fauquier Breeders' Magazine, Vol. 2, pages 27 and 37. 1931.
Peterson, Arthur G., Wheat and corn prices received by producers in Virginia, 1801-1928. Journal of Economic and Business History, Vol. 2, pages 382-391. February, 1930.
Polson, Robert A., Social changes in Walworth County, Wisconsin: A study of trends in town-country relations. Publication of the American Sociological Society, Vol. 25, No. 2, pages 139-142. May, 1931.
Pratt, Avery D., Does the nickel dissolved from the container during pasteurization catalyze the destruction of the vitamins of milk? The Journal of Nutrition, Vol. 3, pages 141-156. September, 1930.
Runnells, R. A., and Thorp, Frank, Jr., The effect of fowl typhoid vaccination upon the macroscopic agglutination test for *Salmonella pullorum* infection. Journal American Veterinary Medical Association, Vol. 72 (New Series 25), pages 90-105. October, 1927.
Runnells, Russell A., and L. S. Meriwether, Some of the factors involved in the slide-method Pullorum test. Journal American Veterinary Medical Association (New Series), Vol. 29, pages 643-647. 1930.
Schoene, W. J., Peach insect investigations proposed for 1930. Proceedings Virginia State Horticultural Society for 1929, pages 71-74. December, 1929.
Schoene, W. J., Leafhopper association on apple. Journal Economic Entomology, Vol. 23, pages 177-182. February, 1930.
Schoene, W. J., Plum curculio studies at Crozet in 1930. Proceedings 35th Annual Meeting of the Virginia State Horticultural Society, pages 134-135. January, 1931.
Schoene, W. J., Leafhopper studies during 1930. Journal of Economic Entomology, Vol. 24, pages 177-180. February, 1931.
Schneiderhan, F. J., The black walnut (*Juglans nigra* L.) as a cause of the death of apple trees. Phytopathology, Vol. 17, pages 529-540. 1927.
Schneiderhan, F. J., Bordeaux mixture, a new and instant method of preparation from the dry, powdered ingredients. Proceedings 33rd Annual Meeting Virginia State Horticultural Society, pages 104-112. 1929.
Schneiderhan, F. J., A study of suspension ratios in Bordeaux mixture prepared from stock solutions and from dry, powdered ingredients. Phytopathology, Vol. 19, page 88. 1929.
Shear, G. M., Studies on inanition in *Arachis* and *Phaseolus*. Plant Physiology, Vol. 6, pages 277-294. 1931.
Swinson, Carl R., F. P. Weaver, A. J. Dadisman, J. J. Vernon, H. P. Gould and J. B. Kincer, Factors influencing the yield of apples in the Cumberland-Shenandoah region of Pennsylvania, Virginia and West Virginia. U. S. Department of Agriculture Technical Bulletin No. 54, 26 pages, 12 figures. December, 1927.
Swinson, Carl R., J. J. Vernon, F. F. Lininger, F. P. Weaver, and A. J. Dadisman, Marketing apples grown in the Cumberland-Shenandoah region of Pennsylvania, Virginia and West Virginia. U. S. Department of Agriculture Technical Bulletin, No. 234, 51 pages, 5 figures, 38 tables. March, 1931.
Wingard, S. A., Tobacco ringspot; a virus disease with wide host range. Phytopathology, Vol. 18, page 133. 1928.
Wingard, S. A., Hosts and symptoms of ringspot, a virus disease of plants. Journal of Agricultural Research, Vol. 37, pages 127-153. 1928.
Wingard, S. A., Some important orchard diseases. Proceedings 35th Annual Meeting of the Virginia State Horticultural Society, pages 143-151. January, 1931.

FINANCES

Tables 1 to 4, inclusive, set forth the fiscal transactions of the station for the period of time covered by this report. The station received each year from the Federal Government $15,000.00 under the Hatch Act and a like amount under the Adams Act. The station received from the Federal Government under the Purnell Act $40,000.00 for the year ending June 30, 1928; $50,000.00 for the year ending June 30, 1929; $60,000.00 for the year ending June 30, 1930; at that time the appropriations provided under the Act for state experiment stations matured, and in subsequent years the station will receive $60,000.00 a year under the Purnell Act.

The supplemental fund includes revenue derived from the sale of farm crops, orchard fruits, livestock and milk which are produced incidentally in the experiments and investigations supported by federal funds; on March 1, 1928, the supplemental fund was merged into the state fund.

The state fund includes the appropriations made by the General Assembly of Virginia for support of the work of the station; and the revenues derived from the sale of produce, etc., incidental to the experiments cared for by the fund. There was also included in this fund an allotment from the appropriation to the State Board of Crop Pest Commissioners for the year ending February 29, 1928, as mentioned in the former report.

The state appropriations from the General Assembly for the support of the work of the station were as follows:

For the year ending:	Appropriation
February 29, 1928	$ 63,000.00
February 28, 1929	70,995.00
February 28, 1930	74,685.00
Four months ending June 30, 1930	33,430.00
June 30, 1931	101,470.00
June 30, 1932	97,470.00

The State Board of Agriculture fund included appropriations for the support of the substations in Augusta, Charlotte and Henry counties. These appropriations were as follows:

For the year ending:	Appropriation
February 29, 1928	$10,000.00
February 28, 1929	10,000.00
February 28, 1930	10,000.00

Beginning March 1, 1930, the budget for these three county stations was merged into the budget of the main station.

Table 1.—Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1927-1928

	Hatch Fund	Adams Fund	Purnell Fund	Supplemental Fund[1]	State Fund	State Board of Agriculture Fund
RECEIPTS:						
Appropriations	$15,000.00	$15,000.00	$40,000.00		$73,755.00	$13,333.33
Balance from previous year				2,653.50	8,501.55	560.48
Farm products, etc.				2,655.44	10,409.59	387.05
Total	$15,000.00	$15,000.00	$40,000.00	$5,308.94	$92,666.14	$14,280.86
DISBURSEMENTS:						
Salaries	$9,216.60	$14,124.92	$23,539.08		$48,712.34	$6,095.38
Labor	3,413.61	42.60	5,437.43	1,301.00	10,737.01	1,544.30
Stationery and office supplies	136.59		432.48		344.08	.55
Scientific supplies, consumable	118.85	117.68	495.23	230.46	511.53	.75
Feeding stuffs	1.20	303.90		1,663.31	4,051.52	169.87
Sundry supplies	407.19	1.25	93.38	41.77	1,591.28	471.85
Fertilizers	13.43			.50	1,125.14	550.21
Communication service	195.13	.59	118.94	9.77	455.77	27.00
Travel expenses	256.57	75.44	7,237.06		4,555.91	112.02
Transportation of things	41.61		37.38	23.86	589.62	103.67
Publications	282.04		315.70		1,052.79	
Heat, light, water and power	158.40		9.99	78.00	650.52	23.58
Furniture, furnishings, fixtures	153.20		583.53		456.13	12.67
Library	274.81		108.74	9.91	1,086.22	
Scientific equipment	104.15	330.62	429.07	555.81	1,465.30	
Livestock				4.50	4,374.54	800.00
Tools, machinery and appliances	128.14	3.00	279.99	86.55	1,500.84	677.89
Buildings and land	95.78		882.00	702.93	7,152.02	3,589.02
Contingent expenses	7.70				119.55	128.10
Balance				[1]600.57	2,134.03	474.00
Total	$15,000.00	$15,000.00	$40,000.00	$5,308.94	$92,666.14	$14,280.86

[1]This fund was merged with the State fund beginning March 1, 1928.

Table 2.—Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1928-1929

	Hatch Fund	Adams Fund	Purnell Fund	State Fund	State Board of Agriculture Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$50,000.00	$72,225.00	$10,000.00
Balance from previous year				2,134.03	474.00
Farm products, etc.				14,305.64	1,079.92
Total	$15,000.00	$15,000.00	$50,000.00	$88,664.67	$11,553.92
DISBURSEMENTS:					
Salaries	$9,283.32	$12,024.95	$30,726.66	$43,134.66	$5,599.92
Labor	3,213.35	1,340.39	6,792.94	11,678.21	2,370.32
Stationery and office supplies	417.30	12.40	201.87	222.53	5.16
Scientific supplies, consumable	153.13	210.47	451.16	593.20	
Feeding stuffs	1.10	441.40	35.90	152.95	113.00
Sundry supplies	297.24	40.01	72.03	2,283.28	357.05
Fertilizers	31.00	2.00	2.25	1,020.11	489.44
Communication service	112.85	2.11	203.42	368.65	40.62
Travel expenses	253.91	22.60	4,223.40	4,297.81	97.75
Transportation of things	37.92			573.86	2.91
Publications	672.43		3,364.92	3,997.14	
Heat, light, water and power	58.70			727.45	30.65
Furniture, furnishings, fixtures	68.58	14.92	1,426.91	271.60	
Library	128.37		291.38	603.64	
Scientific equipment	70.21	600.56	1,275.80	1,292.02	
Livestock				1,310.50	
Tools, machinery and appliances	145.19	284.21	239.55	1,378.20	599.74
Buildings and land	50.40	3.98	691.81	2,460.17	416.92
Contingent expenses	5.00			84.46	12.50
Balance				7,214.23	1,417.94
Total	$15,000.00	$15,000.00	$50,000.00	$88,664.67	$11,553.92

Table 3.—Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1929-1930

	Hatch Fund	Adams Fund	Purnell Fund	State Fund	State Board of Agriculture Fund[1]
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$60,000.00	$82,539.21	$6,666.67
Balance from previous year				7,214.23	1,417.94
Farm products, etc.				12,369.60	441.41
Total	$15,000.00	$15,000.00	$60,000.00	$102,123.04	$8,526.02
DISBURSEMENTS:					
Salaries	$6,872.77	$12,949.86	$36,101.44	$47,619.97	$3,287.75
Labor	3,509.77	1,330.04	5,946.62	13,566.55	1,442.37
Stationery and office supplies	455.11	3.60	371.46	48.16	1.50
Scientific supplies, consumable	197.02	217.98	342.03	241.36	
Feeding stuffs	674.09		116.40	3,015.81	132.00
Sundry supplies	183.12	173.39	269.37	2,579.13	306.96
Fertilizers	111.40		3.74	2,395.02	443.51
Communication service	283.05		153.99	487.60	11.25
Travel expenses	86.11	86.07	5,453.99	5,015.70	107.47
Transportation of things	275.92		15.10	891.58	2.98
Publications	289.35		5,480.58	2,519.02	5.00
Heat, light, water and power	659.60		38.22	665.75	18.11
Furniture, furnishings, fixtures	181.30		1,408.40	180.07	
Library	246.36		35.91	473.52	
Scientific equipment	613.68	74.25	3,229.65	1,709.57	13.00
Livestock			63.70	3,718.00	325.00
Tools, machinery and appliances	49.92	133.25	353.28	3,220.20	800.97
Buildings and land	278.10	31.56	616.12	3,028.81	1,289.19
Contingent expenses	33.33			653.75	9.38
Balance				10,093.47	[1]329.58
Total	$15,000.00	$15,000.00	$60,000.00	$102,123.04	$8,526.02

[1]This fund was merged with the State fund beginning March 1, 1930.

Table 4.—Financial Report. The Virginia Agricultural Experiment Station in Account with Federal and State Appropriations, 1930-1931

	Hatch Fund	Adams Fund	Purnell Fund	State Fund	Soil Survey Fund
RECEIPTS:					
Appropriations	$15,000.00	$15,000.00	$60,000.00	$101,470.00	$7,500.00
Balance from previous year				10,093.47	
Farm products, etc.				8,975.81	
Total	$15,000.00	$15,000.00	$60,000.00	$120,539.28	$7,500.00
DISBURSEMENTS:					
Salaries	$8,617.48	$13,974.84	$42,568.26	$53,175.46	$4,327.50
Labor	4,587.10	970.00	6,171.84	18,089.75	2.79
Stationery and office supplies	45.48		208.56	443.73	5.00
Scientific supplies, consumable	261.10	10.00	312.56	757.73	35.77
Feeding stuffs			504.32	6,577.06	
Sundry supplies	195.46	27.68	210.52	2,130.37	22.87
Fertilizers	18.50			2,442.11	
Communication service	426.33		9.60	634.98	.72
Travel expenses	76.25	4.70	6,642.89	4,907.37	2,597.35
Transportation of things	34.48		10.59	625.02	1.05
Publications			1,793.06	2,206.05	6.96
Heat, light, water and power	107.74		28.74	1,257.46	
Furniture, furnishings, fixtures	15.00		189.23	356.80	39.79
Library	425.49		67.14	389.58	
Scientific equipment	84.98		761.01	1,830.74	76.35
Livestock				6,924.40	
Tools, machinery and appliances	54.91	12.78	368.75	2,493.90	3.50
Buildings and land	49.70		152.93	5,273.67	
Contingent expenses				134.30	
Balance				14,938.80	380.35
Total	$15,000.00	$15,000.00	$60,000.00	$120,539.28	$7,500.00

DEPARTMENT OF AGRICULTURAL CHEMISTRY

The research work in agricutural chemistry is in charge of Dr. W. B. Ellett, chemist, H. H. Hill, associate chemist, and J. F. Eheart, assistant chemist. The department cooperates with several other departments of the station and performs the analytical work connected with the cow feeding project, the pasture investigations, the spray residue problem and several other projects.

Green Manuring Project.—This study has been under way for a number of years and involves a study of the subject by means of field plats under field conditions. In 1929 the investigation was broadened by using lysimeter equipment for measuring the outgo of plant food from Hagerstown silt loam soil, with which was incorporated organic matter from different sources. It has been found that there is a greater outgo of water from the lysimeters in which the soil had received organic matter, particularly during periods of moderate rainfall. The lysimeters which received the mulch of organic matter showed a greater amount of initial nitrate nitrogen, but at the end of the first year the amounts of nitrate nitrogen were practically the same. There were some differences, due to the kind of organic matter used for supplying the mulch. Green rye was readily nitrified. Mature rye, when incorporated as the mulching material, depressed nitrification and the depression was intensified when this material was turned under, but in spite of this fact the amount of nitrate nitrogen recovered in the drainage was always slightly greater than the control. The moisture relationships in this study showed that mulching increased the water holding capacity of the soil. A relatively large amount of calcium carbonate, magnesium carbonate and total bases were contained in the leachings from the lysimeters treated with organic matter in comparison with control lysimeters. The organic matter treatments produced no marked changes in the liberation of potassium and sulphur. The organic matter supplied the soil in this experiment consists of green rye and mature rye. In some cases the organic matter is worked into the soil, and in other cases it is left on the surface of the soil as a mulch.

At the end of two years the amount of plant food leached through the soil showed increases for the mulched lysimeters. The outgo of nitrate nitrogen was slightly greater from the lysimeters in which the organic matter was worked into the soil, and the increase over control lysimeters was about 161 pounds per acre for the green material, and around 40 pounds per acre for the mature rye. Due to the unusually light rainfall in 1930 the amount of leachings was proportionately small. During the second year the experiment showed abundant nitrification where green materials were applied, ranging from 27 to 168 pounds per acre-foot. The experiment the second year also showed that mature rye depressed nitrate formation.

The leaching of carbonates points to interesting results. The application of green rye gave very high increases in calcium and magnesium leachings as compared to mature rye.

The leaching of sulphur is about the same under each treatment. The small amount of potash leached through the soil indicates that this element is in some way fixed in the soil since the outgo of this element was reduced from 25 pounds per acre in the first year of the experiment to about 2 pounds during the second year. This circumstance is in accord with the results of other investigators who have used lysimeter equipment in this connection, for they also observed this fixation effect. Table 5 shows the extent to which mineral elements were leached through the soil in lysimeters during a period of two years.

Table 5.—Effect of green and mature rye, mulched and turned, on the total amount of plant nutrients leached from 2-foot lysimeters over a two-year period

(Results expressed in pounds per acre)

Plant nutrient	Green rye mulched	Green rye turned	Mature rye mulched	Mature rye turned	Control
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Calcium carbonate	862.77	844.97	563.24	480.37	329.73
Magnesium carbonate	160.49	230.85	189.21	129.07	85.39
Total carbonate as calcium carbonate	1,053.08	1,118.71	728.31	633.42	430.98
Sulphur	22.88	14.12	30.09	16.45	14.02
Potassium	24.07	26.31	20.85	22.25	14.39
Nitrogen as nitrate	232.45	250.15	137.79	128.51	88.94

Lysimeter Investigations.—The lysimeter equipment was described in the previous report (pages 26-28). The object of the investigations is to find out what becomes of the plant food elements which are applied to soils, and at the outset the study was confined mainly to lime problems and the effects of applications of lime upon plant food already contained in the soil. Different forms of lime from different sources were used and the methods of applying the lime were described in the previous report (page 27). During each year covered by this report aliquots of the leachings from Hagerstown slit loam and from Norfolk sandy loam were analyzed at regular intervals to determine the amount of plant food leached through the soil. This study has been in progress for nine years. The several kinds of lime from different sources appear to be equally available, but there is a slightly increased neutralizing effect from dolomitic limestone. Calcium carbonate in several forms and burnt lime depress the native magnesium content of the soil as measured in the leachings. The opposite effect was noted where dolomitic limestone was applied. The explanation seems to be that calcium depresses magnesium and magnesium depresses calcium. The addition of organic matter to the soils increased the outgo of calcium and magnesium during the first three years of the investigation, probably due to the fact that a greater volume of water

passed through the rims. At the present time all treatments are giving practically the same amount of percolate for a given depth of soil.

Lysimeter investigations with lime materials, in connection with a coastal plain soil, is nearing completion. This phase of the study was designed for a period of eight years, and will be completed in 1932. It is being carried on in cooperation with the Tennessee Agricultural Experiment Station. Some of the important facts developed in this phase of the study are the reciprocal repression of calcium and magnesium, fixation of native potassium by lime materials, and a tendency toward conservation of lime when applied in small quantities at frequent intervals as against large applications over longer periods of time.

It has been observed that the intensity of electric storms is closely correlated with the amount of nitrate nitrogen brought to the soil in the rainfall during the summer months. This feature of the study is being checked up closely.

Table 6.—The total outgo of lime and magnesia from Hagerstown silt loam soil for a period of eight years, expressed in pounds per acre after one treatment with lime in its several forms [1]

Rim No.	Treatment	$CaCO_3$	$MgCO_3$	$MgCO_3$ equivalent to $CaCO_3$	Total as $CaCO_3$
	1-Foot Series				
		Pounds	*Pounds*	*Pounds*	*Pounds*
49	Rain gauge	623.84	192.81	228.63	852.47
45	Control	889.67	322.47	382.38	1272.05
2	Limestone	1369.43	352.48	417.97	1787.40
3	Dolomite	1269.22	514.00	609.50	1878.72
4	Oyster shells	1381.06	310.51	368.20	1749.26
5	Burnt lime	1364.26	314.73	373.21	1737.47
6	Burnt dolomite	1218.00	509.07	603.66	1821.66
7	Synthetic burnt dolomite	1188.19	486.43	576.81	1765.00
1	Marl	1275.11	329.99	391.30	1666.41
47	Stable manure	895.40	313.12	371.30	1266.70
	2-Foot Series				
46	Control	1415.35	396.70	470.41	1885.76
16	Limestone	1627.22	399.42	473.63	2100.85
17	Dolomite	1559.50	486.72	577.15	2136.65
18	Oyster shells	1747.23	371.12	440.07	2187.30
19	Burnt lime	1779.86	405.47	480.81	2260.67
20	Burnt dolomite	1345.29	592.40	702.47	2047.76
21	Synthetic burnt dolomite	1472.44	545.26	646.57	2119.01
	4-Foot Series				
64	Control	608.68	323.74	383.89	992.57
15	Marl	781.89	436.21	517.26	1299.15
50	Marl	723.71	393.24	466.30	1190.01
51	Limestome	810.70	378.10	448.35	1259.05
52	Dolomite	685.81	447.83	531.04	1216.85
53	Oyster shells	747.37	348.36	413.09	1160.46
54	Burnt lime	811.37	413.92	490.83	1302.20
55	Burnt dolomite	1113.80	563.43	668.12	1781.92
56	Synthetic burnt dolomite	879.40	541.02	641.54	1520.94

[1] Liming materials were applied once at the beginning of the experiments at rates equivalent to one ton of burnt lime per acre.

Table 7.—The total outgo of lime and magnesia from Hagerstown silt loam soil for a period of eight years, expressed in pounds per acre after treatment with lime in its several forms together with organic matter in the form of clover hay[1]

Rim No.	Treatment	$CaCO_3$	$MgCO_3$	$MgCO_3$ equivalent to $CaCO_3$	Total as $CaCO_3$
		1-Foot Series			
		Pounds	*Pounds*	*Pounds*	*Pounds*
8	Marl	1703.45	416.25	493.59	2197.04
9	Limestone	1375.53	448.11	531.37	1906.90
10	Dolomite	1547.63	569.82	675.69	2223.32
11	Oyster shells	1686.93	480.68	569.99	2256.92
12	Burnt lime	1531.81	424.64	503.54	2035.35
13	Burnt dolomite	1534.65	639.56	758.39	2293.04
14	Synthetic burnt dolomite	1481.49	613.70	727.73	2209.22
		2-Foot Series			
22	Marl	1977.02	475.54	563.90	2540.92
23	Limestone	1954.85	527.62	625.65	2580.50
24	Dolomite	1894.00	494.96	586.92	2480.92
25	Oyster shells	2022.21	434.58	515.27	2537.48
26	Burnt lime	1857.21	476.94	565.56	2422.77
27	Burnt dolomite	1993.48	520.32	617.00	2610.48
28	Synthetic burnt dolomite	1925.15	529.49	627.87	2553.02
44	Clover hay	1240.66	525.54	504.61	1745.27
		4-Foot Series			
57	Marl	1412.49	759.47	900.58	2313.07
58	Limestone	1539.88	823.36	763.40	2303.28
59	Dolomite	1563.73	750.34	889.75	2453.48
60	Oyster shells	1466.72	686.76	814.36	2281.08
61	Burnt lime	1509.86	447.48	530.62	2040.48
62	Burnt dolomite	1421.11	678.94	805.09	2226.20
63	Synthetic burnt dolomite	1593.21	698.40	828.16	2421.37

[1]Liming materials were applied once at the beginning of the experiments at rates equivalent to one ton of burnt lime per acre. Clover hay was applied to the soil at the rate of twelve tons per acre.

In 1929 the results of one phase of this study were published in the Journal of Agricultural Research in a paper entitled, "Effect of Lime Materials on the Outgo of Sulphur from Hagerstown Silt Loam Soil," and some of the conclusions were: (1) The application of lime materials does not give marked increases in sulphur outgo but the biological processes which transform sulphur in the soil appear to be stimulated; (2) the growing of millet and clover on the soil tended to diminish the outgo of sulphur in the drainage water; (3) clover residues increased plant growth and along with the rainfall added sulphur to the soil in sufficient quantities for a second crop of millet and the bare soil lost 2.19 pounds more sulphur per acre than the soil containing the millet stubble; (4) the addition of one to three feet of subsoil diminished the amount of sulphur passing out in the drainage water.

Tables 6 and 7 show the total amounts of calcium carbonate and magnesium carbonate leached from the soil during a period of eight years.

Cow Feeding Investigation.—The department of agricultural chemistry makes the chemical analyses involved in this investigation and cooperates with the dairy husbandry department in the project. These investigations will be discussed more fully in the section of this report which deals with the work in dairy husbandry. It requires the time of one chemist to perform the analytical work required in this investigation.

Effects of Nitrogenous Fertilizers on the Protein Content of Pasture Grasses.—This investigation is being conducted in cooperation with the department of agronomy and requires several hundred analyses each year. The problem is attacked from the following angles: (1) Time of application of the nitrogenous fertilizers. The work at this station and recent work in England and Germany shows that nitrogen applied to pastures in large amounts (provided the other fertilizer requirements are met) increases the protein content of grasses materially. The carrying capacity of the land for cattle is increased and the grazing season is lengthened. (2) Sources of nitrogen. It is thought that the source from which the nitrogen in the fertilizer is derived will have an influence on the plant population and on the composition, yield of dry matter and protein content of grasses. (3) Rate of application of fertilizers. In these studies the nitrogenous fertilizers were applied at different times and in different amounts so as to observe seasonal effects.

When the grass is about four inches high it is clipped and the crude protein content is determined as compared with check plats which received no nitrogenous fertilizer. It was also noted that heavy applications of nitrogenous fertilizer decrease the amount of white clover present in the plats. During the second year all the nitrogenous treatments in one series of plats (series A) restricted the amount of clover in the plats and the yields from the check plats, where no nitrogen was applied, was greater than the plats receiving nitrogen, with the possible exception of urea.

The amount of white clover in a pasture sod has an important relation to the protein content of the grass clipped from the pasture and its presence may be more desirable due to its high nutritive value and palatability. An analysis showed that young clover contained 30.13 per cent of crude protein, while bluegrass from the same plat contained 23.31 per cent of crude protein.

The young tender grasses have a very high protein content. Some of the cuttings from the plats have shown as high as 35 per cent crude protein, and where heavy applications of nitrogen have been made the yields of dry matter are very high in the early part of the grazing season. The factors affecting the yield other than fertilizers are temperature and moisture. During the summer months the yield and percentage of protein diminishes, and increases again during the fall months. The high protein content of the clippings enables one to dry and compress them so that they can be utilized during the winter

months as a high protein concentrate comparing favorably with cottonseed and peanut meals.

In 1930 only two clippings were made on the plats, due to the extreme drought. In 1931, with an abundance of rain, seven clippings have already been made. These clippings are now being analyzed and the results will be available next spring. Tables 8 and 9 show the treatments received by the plats in Series A for the years 1928 and 1929, together with the quantity of dry matter and the quantity of crude protein produced per acre. Table 10 shows data for a different fertilizer treatment on another series of plats.

Table 8.—Effects of the addition of the varying amounts of nitrogen from different sources on the protein content of pasture grasses. Series A, 1928 [1]

Plat No.	Treatment	Date of application	Dry matter per acre	Protein per acre	Cuttings
			Pounds	*Pounds*	*Number*
1	50 lbs. N from $NaNO_3$	April 1	3280.60	642.67	9
2	100 lbs. N from $NaNO_3$	April 1	4065.60	861.09	9
3	150 lbs. N from $NaNO_3$	April 1	4683.70	1046.75	9
4	Check. No nitrogen		3585.58	749.73	9
5	50 lbs. N from $(NH_4)_2SO_4$	April 1	3273.35	631.76	9
6	100 lbs. N from $(NH_4)_2SO_4$	April 1	4059.24	815.09	9
7	150 lbs. N from $(NH_4)_2SO_4$	April 1	4492.12	943.34	9
8	Check. No nitrogen		4276.14	852.09	9
9	50 lbs. N from urea	April 1	5435.01	1253.31	9
10	100 lbs. N from urea	April 1	4750.76	1080.43	9
11	150 lbs. N from urea	April 1	5305.25	1122.59	9
12	Check. No nitrogen		4792.50	1017.92	9
13	100 lbs. N from $NaNO_3$	April 1 and July 1	5543.01	1171.24	9
14	100 lbs. N from $(NH_4)_2SO_4$	April 1 and July 1	4897.78	1094.65	9
15	100 lbs. N from urea	April 1 and July 1	4467.62	938.20	9
16	Check. No nitrogren		1998.32	842.01	8
17	100 lbs. N from $(NH_4)_2SO_4$	July 1	2368.57	519.90	4
18	100 lbs. N from $(NH_4)_2SO_4$	Sept. 1	361.18	91.11	1
19	50 lbs. N from $(NH_4)_2SO_4$	April 1 and July 1	3950.44	723.65	9
20	50 lbs. N from $(NH_4)_2SO_4$	April 1, July 1, Sept. 1	3898.18	754.89	9
21	Check. No nitrogen		2305.05	347.60	9
22	100 lbs. N from $NaNO_3$	April 1 left for hay	6867.96	984.86	2
23	100 lbs. N from $(NH_4)_2SO_4$	April 1 left for hay	7036.57	1020.59	2
24	100 lbs. N from urea	April 1 left for hay	7711.02	1064.12	2
25	Check. No nitrogen	Left for hay	4643.67	553.06	2

[1] All plats received 1 ton ground limestone and 500 pounds of 16 per cent superphosphate annually as a basic treatment.

The Spray Residue Problem.—In 1926 a study was made of the spray residue problem with particular reference to the amount of arsenic oxide remaining on the fruit at picking time, when the regular spraying schedule is followed in the orchard. Experiments were conducted in the laboratory at that time to determine the effectiveness of various reagents for the removal of spray residue from the fruit, and it was found that a weak solution of hydrochloric acid in water was effective for this purpose. (See pages 28 and 142-148 of the former report.) During the year 1930 the spray residue problem became acute in Virginia apple orchards, and this department cooperated with other departments of this station and with the State Department of Agriculture in assisting fruit growers to overcome this difficulty.

Clarification of Plant Juices.—In connection with a study being made in our agronomy department on the composition of the juice of corn plants

Table 9.—Effects of the addition of varying amounts of nitrogen from different sources on the protein content of pasture grasses. Series A, 1929 [1]

Plat No.	Treatment	Date of application	Dry matter per acre	Protein per acre	Cuttings
			Pounds	*Pounds*	*Number*
1	50 lbs. N from $NaNO_3$	April 1	2281.05	508.20	6
2	100 lbs. N from $NaNO_3$	April 1	2484.42	546.81	6
3	150 lbs. N from $NaNO_3$	April 1	2252.48	508.82	6
4	Check. No nitrogen		2496.73	594.34	6
5	50 lbs. N from $(NH_4)_2SO_4$	April 1	2323.99	534.38	6
6	100 lbs. N from $(NH_4)_2SO_4$	April 1	2251.05	464.48	6
7	150 lbs. N from $(NH_4)_2SO_4$	April 1	2424.77	539.97	6
8	Check. No nitrogen		2868.48	650.39	6
9	50 lbs. N from urea	April 1	2876.06	725.48	6
10	100 lbs. N from urea	April 1	2851.70	732.87	6
11	150 lbs. N from urea	April 1	3629.38	854.01	6
12	Check. No nitrogen		3077.58	771.17	6
13	100 lbs. N from $NaNO_3$	April 1 and July 1	2728.33	654.58	6
14	100 lbs. N from $(NH_4)_2SO_4$	April 1 and July 1	2342.77	550.31	6
15	100 lbs. N from urea	April 1 and July 1	2515.37	532.26	6
16	Check. No nitrogen		2333.61	492.05	6
17	100 lbs. N from $(NH_4)_2SO_4$	July 1	2081.01	474.97	6
18	100 lbs. N from $(NH_4)_2SO_4$	Sept. 1	2199.07	408.98	6
19	50 lbs. N from $(NH_4)_2SO_4$	April 1 and July 1	1727.59	360.99	6
20	50 lbs. N from $(NH_4)_2SO_4$	April 1, July 1, Sept. 1	1964.12	423.84	6
21	Check. No nitrogen		2089.64	495.45	6
22	100 lbs. N from $NaNO_3$	April 1 left for hay	1640.46	277.89	1
23	100 lbs. N from $(NH_4)_2SO_4$	April 1 left for hay	1820.52	320.96	1
24	100 lbs. N from urea	April 1 left for hay	1886.40	252.40	1
25	Check. No nitrogen	Left for hay	477.28	101.71	1

[1] All plats received 1 ton ground limestone and 500 pounds of 16 per cent superphosphate annually as a basic treatment.

as an indicator of the nutrient needs of the plants, a problem was encountered in making the determinations by reason of the fact that it was necessary to clarify the solution before the determinations could be made accurately. H. H. Hill developed a new method for the clarification of plant juices which proved effective for the purpose. This method was described in Science in May, 1930.

Since the publication of this method it has been found that in evaporating the clarified portion of the juice extreme care must be exercised so as not to allow the solution to bake on the water bath. The portion for analysis should be evaporated so that the solution just moves in the dish when it is rotated.

When adding the phenoldisulphonic acid the dish containing the portion for analysis should stand on a beaker containing cold water, preferably crushed ice. This point must also be observed when developing the yellow color with ammonia water. In other words, care must be exercised at all times so as to develop as little heat as possible during the entire procedure or otherwise brown tints may develop which will obscure the yellow color characteristic of this method of estimating nitrate nitrogen.

Another point developed since the first publication of the method concerns the length of time the phenoldisulphonic acid should stand on the evaporated portion. It is customary to add the acid and allow it to stand 10 minutes. This may be reduced to 6 minutes without objectionable results.

This method not only gives good results with plant juices but with soil extracts, and filter-plant effluent as well.

Table 10.—Effects of the addition of varying amounts of nitrogen from different sources and different fertilizer treatments on the protein content of pasture grasses. Series B, 1929 [1]

Plat No.	Treatment	Date of application	Dry matter per acre	Protein per acre	Cuttings
			Pounds	*Pounds*	*Number*
	Lime and Phosphate Basic Treatment				
1	100 lbs. N from $NaNO_3$	April 1	1440.09	306.78	6
2	100 lbs. N from $(NH_4)_2SO_4$	April 1	1538.36	344.62	6
3	16-⅔ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1393.96	294.36	6
4	Check. No nitrogen		1235.62	253.66	6
5	33-⅓ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1757.83	384.74	6
6	50 lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1571.54	368.83	6
7	50 lbs. N from $NaNO_3$	April 1, June 1, Aug. 1	1676.83	381.40	6
	Phosphate Basic Treatment				
8	100 lbs. N from $NaNO_3$	April 1	1634.16	402.25	6
9	100 lbs. N from $(NH_4)_2SO_4$	April 1	1778.95	434.95	6
10	16-⅔ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1605.66	342.86	6
11	Check. No nitrogen		1429.36	316.43	6
12	33-⅓ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1668.60	377.99	6
13	50 lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	2021.80	478.52	6
14	50 lbs. N from $NaNO_3$	April 1, June 1, Aug. 1	1525.04	366.95	6
	Lime Basic Treatment				
15	100 lbs. N from $NaNO_3$	April 1	1704.35	413.19	6
16	100 lbs. N from $(NH_4)_2SO_4$	April 1	1637.61	354.99	6
17	16-⅔ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1484.19	332.78	6
18	Check. No nitrogen		1591.95	386.49	6
19	33-⅓ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1939.93	467.19	6
20	50 lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	2016.27	475.73	6
21	50 lbs. N from $NaNO_3$	April 1, June 1, Aug. 1	1625.78	412.97	6
	No Basic Treatment				
22	100 lbs. N from $NaNO_3$	April 1	1650.38	387.84	6
23	100 lbs. N from $(NH_4)_2SO_4$	April 1	1695.72	393.23	6
24	16-⅔ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1188.77	253.84	6
25	Check. No nitrogen		1224.73	248.93	6
26	33-⅓ lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1366.82	299.70	6
27	50 lbs. N from $(NH_4)_2SO_4$	April 1, June 1, Aug. 1	1685.13	407.65	6
28	50 lbs. N from $NaNO_3$	April 1, June 1, Aug. 1	1591.34	338.05	6

[1]The basic treatment was as follows: ground limestone, 2 tons; superphosphate, 500 pounds; and muriate potash, 200 pounds per acre, for the first 7 plats. The second 7 plats received 500 pounds superphosphate and 200 pounds muriate potash. The third 7 plats received 2 tons ground limestone and 200 pounds muriate potash as the basic treatment. The fourth 7 plats received no basic treatment.

DEPARTMENT OF BOTANY AND PLANT PATHOLOGY

Dr. F. D. Fromme, plant pathologist, was in charge of the investigations in this department during the first year covered by this report. Dr. S. A. Wingard, plant pathologist, was in charge for the rest of the time and he was assisted by Dr. G. M. Shear, assistant plant physiologist, R. G. Henderson, assistant plant pathologist, A. B. Groves, assistant plant pathologist, who is located at the Winchester field laboratory, and R. H. Hurt, assistant plant pathologist, who is located at the Piedmont field laboratory at Charlottesville. The investigations deal with a number of important problems in the field of plant pathology and plant physiology.

Black Root Rot of Apple.—Studies of this disease at the station have extended over a period of about 14 years. Special attention has been given to observations on the susceptibility of seedlings and clonal stocks in search of root stocks resistant to the root-rot disease. The tests have included about 2,000 individuals representing 26 horticultural varieties of ***Malus malus***, 9 clonal stocks and 2 other species of ***Malus***,—***M. robusta*** and ***M. zumi***. No stock has been found that is immune to this disease, although some stocks are more resistant to it than others. Earlier in this study it appeared that Northern Spy root stocks were relatively resistant to root rot, but later developments showed that this characteristic was not consistent.

In 1928 experiments were undertaken in the McCue orchard at Greenwood, to test soil sterilization by steam as a control measure for black root rot. The same year acetic acid was used in the Mary Baldwin orchard at Staunton, for sterilizing the soil. Sterilization of the soil by acetic acid did not give satisfactory results. Sterilization of the soil by steam indicates that there is some promise in this method for controlling root rot.

Loose Smut of Wheat.—In this investigation an attempt was made to isolate loose smut resistant strains from the leading varieties of wheat grown in the state, including Fulcaster, Poole and Fultz. These selected strains are being grown year after year in the field and the susceptible selections are being weeded out constantly, while the most promising resistant strains are being propagated and grown in comparison with the best standard wheat varieties to test their relative yielding power.

Bean Rust.—Work on this project was first begun in 1917, and is still in progress. Crosses were made between the Navy bean and the Improved Goddard, and promising plants which showed resistance to bean rust have been selected from generation to generation in the hope of propagating a rust resistant strain of the Navy variety. Crosses were also made between Kentucky Wonder and Marblehead Pole, from the progeny of which selections have been made showing strong resistance to bean rust. Rust resistance was found to be a dominant factor in beans, and all of the F1 plants were resistant. In the second generation there was segregation of these two characters somewhat in accordance with Mendel's law. The field experiments in the summer of 1930 were a complete failure on account of the drought. However, the experiments conducted in the greenhouse were satisfactory and gave results corresponding to those of former years. About 150 duplicate lots of seed are now on hand and in the process of further testing. Some of the resistant Kentucky Wonder strains are now ready for propagation and distribution.

Ring Spot of Tobacco.—Considerable attention has been given to the host limitations of this virus disease. Infection has been secured on 37 different genera of plants which are distributed among 17 different families. Economic plants that are known to be susceptible are tobacco, egg plant, canta-

loupe, cucumber, pumpkin, watermelon, beans, cowpeas, okra, sunflower, and the caster oil plant.

Infection of plants with the virus of ring spot was obtained through the following methods: swabbing, needle puncture, hypodermic injection, grafting, and approach grafting. The most effective method of inoculation, however, has been the swabbing of the leaves in such a way that the leaf hairs would be broken and thus allow the virus to enter.

The virus is short lived in expressed juices, usually not surviving longer than 24 hours, except at very low temperatures. When stored at –18°C. it has retained its infective property for twenty-two months. It will withstand a temperature of 70°C. for about 2 minutes, and one of 60°C. for 5 to 10 minutes. The drying of infected tobacco leaves destroys the virus.

Natural infection has been found on sweet clover, yellow ironweed, petunia, and squash with viruses which produce ring spot-like symptoms when transferred to tobacco. These viruses, however, are not so virulent on tobacco as the true tobacco ring-spot virus. It is suggested, therefore, that these other viruses may be attenuated forms of the tobacco ring-spot virus. Jimson weed and cantaloupe have been found to be natural hosts of the tobacco ring-spot virus. The virus failed to survive the winter in the roots of pokewood plants.

The ring-spot virus can be precipitated and separated from expressed juice with either alcohol or acetone and recovered in water without any appreciable injury to its infective properties. The virus is very readily filterable through Berkefeld filters of N and V grade, and will pass the W grade if the infected plant juice is first freed of solid matter. The infected tobacco juice has been found to be infectious in dilutions as high as 1 to 1,000.

In 1929 considerable attention was given to the occurrence of ring spot in the tobacco fields in the state. This disease was found in the Burley, dark fired, and bright tobacco sections of the state. In Washington County 95 per cent of the tobacco acreage showed some ring spot. In some fields as much as 90 per cent of the plants were infected. The average infection was estimated at 8 per cent, which would probably cause a decrease in yield of about 1 per cent. In the spring of 1930 ring spot was observed for the first time in plant beds. In order to determine whether the virus is transmitted through the seed about 64,500 tobacco seedlings grown from seed collected from diseased plants were observed and not a single one was found to be infected with ring spot. This appears to be proof that the virus is not readily transmitted on or in tobacco seed. Its occurrence in the plant bed, however, indicates that the virus is seed borne to some extent in the case of tobacco. In contrast with this situation, it appears that the ring-spot virus is readily transmitted through petunia seed. Out of 810 petunia seedlings grown from seed collected from diseased plants, 160 developed ring spot.

During 1930 the tabacco ring-spot virus was successfully cross inoculated between tobacco and Irish potatoes. Nevertheless, the virus occurring naturally in apparently healthy potato plants is regarded as being entirely different from the tobacco ring-spot virus.

Many attempts have been made to secure infection on tomatoes with the tobacco ring-spot virus, but all failed until the tomato plants were grafted upon the infected tobacco plants. This method of inoculation resulted in systemic infection on tomato.

Toxicity of Species of Juglans.—It has been observed that certain species of plants growing near black walnut trees suffer in consequence of their proximity to the walnut trees. Our studies have shown that the toxic factor in the black walnut tree is juglone. This substance has been isolated in a pure state from walnut roots, and marked injury has followed its injection into tissues of alfalfa and tomato. Studies were made on oxidation reduction in relation to walnut toxicity. It is thought that resistance and susceptibility of plants to walnut toxicity may be related directly to differences in reducing intensity to the extent that the cells of certain plants (resistant species) may be able to reduce the toxic quinone to its hydro-form. The roots of susceptible species may be unable to make this reduction.

Drought-Spot of Tobacco.—Preliminary studies show drought-spot to be a disease that was unusually prevalent in Virginia during the summers of 1925 and 1928, and due to a condition of unbalanced nutrition. Extensive fertilizer experiments are being made to show the relationships which may exist between the effect of various fertilizer materials, the rate of their application, the method of application and the occurrence and severity of the drought-spot disease under field conditions. After two years of fertilizer tests the following points seem to be significant: drought-spot appears to be a disease of the mature tobacco plant; nitrogen increases the tendency toward spotting, whereas potassium and chlorine, and to a less extent phosphates, tend to decrease spotting.

In 1930, experiments were conducted in the greenhouses to determine whether drought-spot could be induced in tobacco plants by means of abnormal nutrient and water relations. The results of these experiments showed that abnormal water relations alone will not produce drought-spot, but when abnormal water relations are combined with a lack of vigor in plant growth from one or more causes, drought-spot appears.

Snapdragon Rust.—Rust is a very destructive disease of snapdragons, both in greenhouse and garden. A study was undertaken to find a method of avoiding losses from this disease, and studies are being made on the resistance of strains of snapdragons to rust. Rust resistant hybrids, which were obtained by selection from hybrids already produced by Dr. Mains, of Indiana, seem to be breeding true to type and they possess rust resistant characters.

In addition to these studies tests were made of 160 commercial varieties for rust resistance. Considerable differences were found in these varieties. The most promising varieties will be re-tested in succeeding years.

Winchester Field Laboratory

A number of problems, important to fruit growers in the valley and northern Virginia, are being studied at this laboratory.

Studies of the ejection of ascospores of the apple scab fungus, which have covered a period of six years, may be summarized as follows: At Winchester, under varying seasonal extremes of weather, one may expect ejections of ascospores during the months of April, May, June, and July. Under average conditions they are not liberated before the middle of April nor later than the middle of June, a period of 60 days. There are 12 periods of spore ejection in the average season. The minimum number has been 9 and the maximum 16.

Studies of the intensity of cedar rust infection of the apple in relation to distance from cedar trees were made during three seasons, and may be summarized as follows: If the intensity of infection at one mile is rated 100, that at 1½ miles will be 70, at 2 miles it will be 32, and at 2½ miles it will be 4. Cedars should be eradicated from a 2-mile zone for adequate protection.

Climatic data collected at Winchester over a 13-year period, 1916-1928, inclusive, reveal some important facts in connection with disease occurrence. Rainfall has been found to be the most important factor in disease occurrence, and temperature the second most important. Cool weather in combination with rainfall and high humidity is very conducive to apple scab development, while excessive hot weather in combination with high humidity creates a condition favorable for bitter rot infection. Rainfall during the months of April, May, and June, particularly in May, is the determining factor in scab occurrence.

Tests on the durability of suspensions of Bordeaux mixture with varying proportions of copper sulphate and lime were made on a large scale, and many interesting data were obtained. It was found that chemical hydrated lime is an excellent form of lime for making Bordeaux mixture.

An experiment on thinning apples conducted in the Barr-Miller orchard at Winchester in 1928 showed that thinning pays well, both in quality of fruit and in total yield. The total production of the three thinned trees was 62 boxes while it was only 55 boxes for the unthinned trees. Likewise, thinning produced a substantially higher percentage of No. 1 apples.

In 1930 a study was made of the value of different spray materials in the control of powdery mildew of apple, a disease which is difficult to control. Gray nickel flotation sulphur gave the best control of any of the materials used. However, it gave only 88.1 per cent control.

A study of water-core in apple fruits indicated that the water cored condition in apples soon disappeared when the fruit was placed in storage, either common or cold storage.

Observations were made on the effects of the 1930 drought on apple trees in Northern Virginia. Many orchards are showing very severe injury. The Ben Davis trees are the hardest hit in the Winchester district.

Piedmont Field Laboratory

Work at this laboratory involves the study of orchard diseases in the region around Staunton, as well as across the mountains in the vicinity of Charlottesville and Crozet.

In connection with experiments on the control of apple scab, several spray materials and combinations of materials were tried out, and a new material was developed in calcium monosulphide, which has proved to be more satisfactory than any other available material. Calcium monosulphide has now been used four years, and it is giving satisfactory results. There is less burning of fruit and foliage when this material is used, and it is equally as effective as lime-sulphur in the control of apple scab. Calcium monosulphide also proved to be an excellent fungicide for the summer spraying of peaches. Commercial fruit growers have also given this material extensive tests in recent years, with satisfactory results on both apples and peaches.

A study was made of climatic data at Staunton for a period of 24 years, 1905-1928, inclusive. It was found that the mean temperature of March is a very important factor in determining the apple crop of any particular season. In the work at the Piedmont field laboratory particular attention is given to the following points: (1) Careful recording of climatic data and their relation to disease development; (2) observation of the occurrence and importance of the various diseases of apples and peaches; (3) studies on methods of controlling the most important diseases of apples and peaches; (4) the development of new fungicides and insecticides.

A study was made of waste sulphite liquor from paper mills as an adjuvant to certain spray materials. Waste sulphite liquor occurs on the market in two forms, namely, a brown powder and a heavy syrup-like liquid. The dry powdered form is known to the trade by the names of goulac, bandarene flour, and bindex powder, and the liquid form under the trade names of glutrin, bandarene liquid, bindex liquid and waste sulphite liquor. Experiments have shown that these two materials can be substituted for calcium caseinate in the preparation of cold-mix oil emulsions and in dry-mix sulphur-lime. Results from the use of this material have been entirely satisfactory, more so than in the case of calcium caseinate.

In connection with the peach spraying experiments, it was found that zinc Bordeaux (4 pounds zinc sulphate, 4 pounds hydrated lime, and 50 gallons

water) will prevent arsenical burning on peaches. Arsenate of lead can be added to this material as well as such fungicides as dry-mix and Cal-Mo-Sul. The zinc Bordeaux spray was developed by Dr. W. J. Roberts, of the U. S. Department of Agriculture, for the control of bacteriosis of peaches.

R. H. Hurt, the pathologist in charge at this laboratory, has developed a dry-mix sulphur-lime material which he calls Virginia dry-mix. It consists of the following: Dusting sulphur, 50 pounds; hydrated lime, 42 pounds; powdered lignin pitch (goulac), 8 pounds. This material is used at the rate of 8 pounds to 50 gallons of water on peaches, and 10 to 12 pounds to 50 gallons of water on apples.

DEPARTMENT OF ENTOMOLOGY

The station work in this department is in charge of Dr. W. J. Schoene, entomologist, assisted by G. W. Underhill, associate entomologist; L. R. Cagle, assistant entomologist; A. M. Woodside, assistant entomologist; Dr. W. S. Hough, entomologist in charge of the investigations at the Winchester field laboratory; and N. A. Eaton, Jr., assistant entomologist in charge of the investigations at the Piedmont field laboratory. A number of problems connected with the control of insect pests are being studied and useful and practical results have come out of these studies.

The Codling Moth.—During the past 10 years the codling moth has received special study. The life history of this insect has been observed in the principal orchard sections of the state. The development of the insect is recorded accurately and the habits of the insect are observed. A detailed study is being made as to the way in which the codling moth larva takes its food, and its resistance to poison. A large number of caterpillars are being observed in captivity for the purpose of supplying fruit growers timely information regarding the dates for the several spray treatments.

A comparison is being made as to possible resistance of apple worms to arsenical sprays to find out whether there is a difference between apple worms from the western states and apple worms in northern Virginia. This study is designed to find out more about the nature and cause of resistance to poisons as exhibited by the strains of worms. The results so far indicate that tolerance to spray materials is not specific for arsenic, but also holds true for such insecticides as creolite, barium fluosilicate and rotenone. In the fiscal year 1929-1930 Dr. Hough reared 30,000 codling moth larvae at the Winchester laboratory in connection with this phase of the investigation. The life history of the codling moth in Virginia is described in considerable detail in Bulletin No. 261.

The Red-Banded Leaf-Roller.—The leaf-roller, *Eulia velutinana*, belongs to a class of insects which is very troublesome to fruit growers. The caterpillars draw the leaves together with strands of silk and then feed on the

inside of the webbed foliage. The larvae are very resistant to poison, and they feed almost entirely on the under side of the leaves and within the webbed foliage. The life history and control methods for this insect were studied over a period of 4 or 5 years. The results of this study were published in Bulletin No. 259, which describes the life history and habits of this insect and gives recommendations for its control.

Spraying Equipment.—In connection with the studies on methods for controlling the codling moth and the leaf-roller, experiments were made on devices for improving the effectiveness of spraying by increasing the pressure and by new adjustments of the nozzles. It was found that by applying a larger volume of spray material at a pressure of 350 pounds the leaves on the trees were turned sufficiently to cover both sides with the spray material. Moreover, the operation of spraying is speeded up and the work can be done more quickly. Bulletin No. 260 describes the studies on orchard spraying, and spray equipment. The nozzle arrangement worked out in this study (Figure 5) is now being used quite generally in the fruit growing sections of the eastern United States.

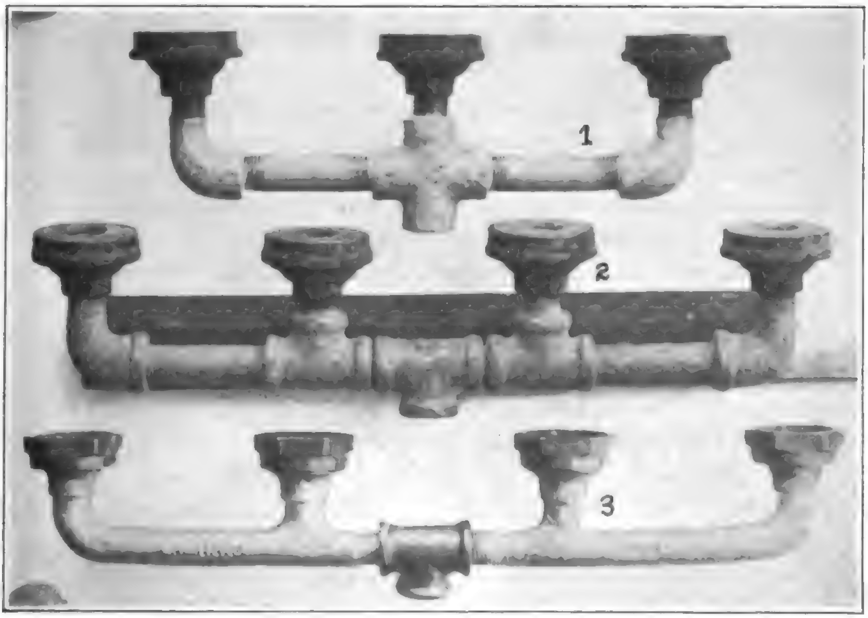


Fig. 5.—Satisfactory types of nozzle heads

The Woolly Aphis.—This investigation is being conducted at Blacksburg and in a nursery near Richmond, and the object is to determine the method of spread of young aphids from one apple tree to another. The comparative resistance of root stocks to woolly aphis is being investigated. To

this end a limited number of apple trees are being grown on their own roots to find out whether resistant forms can be found. Careful observations have been made on the movement of aphids from plant to plant at different seasons of the year. Methods of growing apple trees are being tested to find whether the time of planting the grafts and methods of cultivating them may be adjusted to reduce injury from the woolly aphis. Two years ago this study was extended to include orchard trees as well as nursery stock.

The Peach Moth.—This insect has been studied in New Jersey, Pennsylvania, Maryland and Virginia continually since 1918. Investigations have also been conducted in Ohio and New York. Its life history has been worked out, but no practical remedy for its control has been found. Arsenical poisons applied to the fruit and foliage are not effective. Many experiments were made with spray materials and insecticides to destroy the cocooned larvae by contact poisons. Other tests were made to determine the possibility of poisoning larvae by spraying the bark of fruit trees with arsenic. It was found that sprays or washes containing paradichlorobenzine dissolved in kerosene and carbon disulphide or kerosene alone are deadly to the larvae after they have finished feeding and spun their cocoons. It seems certain that methods will be devised whereby the fruit grower may destroy the worms that cocoon in the picking baskets and in the crevices of the packing house. The insect passes the winter period in the packing house or under rubbish, or in other quarters which furnish protection to it, and if methods are devised for reducing their numbers during the winter period there will be less damage from this pest during the growing season. At the present time the studies of the peach moth deal principally with the following points: (1) Effect of certain spray treatments; (2) movement of adults from apples to peaches in the spring, then back to apples in the fall; (3) effect of the cultivation of the soil; (4) methods of killing worms in packing sheds. The habits of worms and their responses to light are also being studied. Arrangements have been made with representatives of the U. S. Bureau of Entomology to liberate in Virginia orchards the parasite *Macrocentus ancylivora,* which is reported to be very effective as a parasite of the peach moth in other sections of the United States.

Parasite of the Peach Moth.—In 1928 an investigation was undertaken for the breeding of *Trichogramma minutum* on eggs of the grain moth, *Sitotroga cerealella.* Grain moths are reared in large numbers for the purpose of securing grain moth eggs. The *Trichogramma* parasite was liberated in several peach orchards in the state and in a few instances they have been recovered, indicating that they continued to live and multiply in the orchard. The use of parasites for combating insect pests has long been practiced in some regions but it is a comparatively new venture in the eastern part of the United States.

Four incubators were constructed especially for the rearing of grain moths, and during the winter of 1929-1930 large numbers were reared. The parasites were secured also, without difficulty, and a large number of them were distributed to peach orchards in the state. It is planned that this work will be continued until the usefulness of these parasites in reducing the number of peach moths in the orchards is ascertained. In the fall of 1930 evidence was obtained to the effect that the parasites were reducing the number of peach moths; and parasitized eggs of the peach moths were found in the orchard where parasites had been liberated.

The Leafhopper.—Five years ago a study was undertaken concerning the species of leafhoppers present, as well as the time of year when the most injury occurs, and the character of injury caused in apple orchards by these pests. It has been found that certain varieties of apples are particularly susceptible to injury from certain species of leafhopper. One point which needs to be determined is whether or not the abundance of leafhoppers in orchards is due to the presence of other crops. It has been found that leafhoppers are much more numerous in orchards which are well sprayed and well fertilized, and they are usually absent, or present in very small numbers, in neglected orchards. Apparently the succulency of the foliage is largely responsible for their presence in well cared for orchards. Wet weather is unfavorable for the development of leafhoppers, and dry weather is favorable for their development. During the drought of 1930 leafhoppers were found only on trees which were favorably located with respect to moisture supply. Trees which were not receiving sufficient water had very few leafhoppers on them.

Four species of leafhoppers have been found to be injurious to the foliage of apple trees. The species which is generally present and which does most damage is the rose leafhopper, *Typhlocyba pomaria.* This insect passes the winter on the apple tree as an egg, the egg being found on one or two-year-old wood. The eggs hatch in May and June, and both nymphs and adults feed on the foliage. The first brood adults disappear about July, after they have deposited their eggs. The second brood of nymphs and adults occurs during the latter part of August and September and this is the brood which causes the severe spotting of the leaves and fruit.

Spray Russeting.—Studies on spray russeting have been in progress nearly eight years. Some varieties of apples suffer more than others from injury caused by spray materials. The effect of lead arsenate and lime-sulphur on Ben Davis apples is well known. In these experiments involving several varieties of apples in orchards near Winchester special attention is being paid to the injury caused by arsenate of lead when used alone and in combination with fungicides. Attention is also being given to the influence of rainfall, high temperature, the pressure used in spraying and volume of material applied per tree. In 1929 a total of 22 plats of 10 trees each of the Ben Davis

variety were used in spraying experiments. Iron oxide, lime and a prepared mixture (fluxit) were used as correctives to reduce spray injury. Substitutes for lime-sulphur, which are known to liberate free arsenic in our combination sprays are being tried as follows: Sulphur-lime, dry-mix, calcium sulphide, and three flotation sulphurs. All of these substitutes appear to reduce spray injury somewhat. All sulphur fungicides, in combination with lead arsenate, injured the fruit when applied in extremely warm weather (about 90 to 95 degrees F.).

Aphids of the Apple and Their Control.—Several species of aphids are injurious to apple trees, including the *Aphis sorbi, Aphis avenae* and *Aphis pomi.* The object of this investigation is to find effective control measures for these pests. These aphids do not migrate from one tree to another during the spring of the year, and injuries from them can be prevented by thorough applications of suitable spray materials at the right time.

Dr. Hough has given special attention to this study at the Winchester field laboratory. He sprays the eggs with different materials in the hope of finding some material which is toxic to the eggs. He uses such spray materials as tar distillate and dinitro-orthocresol. Penetrol in combination with nicotine sulphate in the delayed dormant spray was tested. The value of various oil sprays used alone and in combination with an aphicide were also tested in the delayed dormant spray. Tar distillates were used in dormant spraying with excellent results in controlling the aphids in the egg stage. Combinations of oil emulsions alone and with nicotine sulphate and derris applied in the delayed dormant spray showed clearly the advantage of nicotine sulphate as an aphicide.

Green Soldier Bug.—G. W. Underhill made a study of the life history of the green soldier bug, *Nezara hilaris,* because this insect is often troublesome and sometimes causes severe injury to fruits and vegetables. In this study it has been shown that the insects feed on wild plants, migrating from plant to plant as the season advances. Early in the season it feeds on the tender twigs of forest trees and later upon the seed pods of locust. If, for any reason, these sources of food give out, the insects attack fruits and vegetables. The green soldier bug has been an important pest at times in peach orchards. It has also inflicted severe damage in fields of lima beans. While feeding, the adults and the nymphs inject into the bean the spores of the yeast-spot disease; and this disease causes the pods of the beans to wilt and fall off. The green soldier bug does little damage to cultivated plants so long as it finds a succession of species of trees or plants which provide food throughout the year. Injury to cultivated plants occurs principally when the wild hosts cease to furnish food.

Plum Curculio.—Owing to the very severe loss in the peach orchards in this state during the summer of 1929 a special project for the study of the plum curculio was undertaken, and A. M. Woodside was assigned to this study.

The life history of the plum curculio is being studied carefully for this latitude, particularly at Charlottesville and Staunton. Observations are also being made in peach orchards at Timberville, Waynesboro and Crozet. During the past two years it has been learned that the adults of this insect migrate to the peach orchard from the woods over a considerable period of time. The migration may continue as long as two or three weeks, and during this period the curculio may be found in greatest abundance on the trees nearest the woods. The plum curculio is a serious pest of both peaches and apples.

DEPARTMENT OF HORTICULTURE

The station investigations in horticulture are in charge of Dr. F. W. HofMann, associate horticulturist, assisted by R. C. Moore, assistant horticulturist. The investigations in this department include projects of practical importance to fruit growers in Virginia on the following subjects: (1) Factors which influence fruitfulness of apple trees; (2) variety studies of fruits; (3) local orchard management experiments; (4) a study of the paper carton as a package for marketing apples; (5) breeding apples; (6) breeding grapes; (7) Japanese millet as an orchard cover crop. The progress of the investigations on these several projects is discussed in the paragraphs which follow.

Factors Influencing Fruitfulness of Apple Trees.—This investigation has been in progress since 1911. Three methods of soil management are employed, namely, intensive tillage of the soil during the growing season, moderate tillage of the soil during part of the growing season, and sod management, which involves no tillage at all. These three systems of soil management are crossed by plats which receive different fertilizer treatments along with check plats which receive no fertilizer treatments. Nitrogen, potash and phosphoric acid are applied singly and in combination on particular plats.

Interesting conclusions have been drawn from these experiments, some of the most important of which were stated in Bulletin No. 269, entitled, "Soil Management Experiments with the Application of Fertilizers in Apple Orchards," issued in March, 1930. It was shown that orchards in the Piedmont and Valley regions of Virginia responded in a significant way as regards tree growth and yield of fruit in both cultivated and sod systems of soil management when treated with a complete fertilizer carrying nitrogen, phosphoric acid and potash. An analysis of experimental data from the stations in Virginia, West Virginia, Pennsylvania and New York led to the same conclusion. Under certain soil conditions apple trees respond favorably to applications of nitrogenous fertilizers alone. When we take into account the fact that apple trees remain on the same land a long time, and that their growth and fruitfulness depend upon the presence in the soil solution of adequate amounts of the essential plant food elements, it is obvious that the fertilizer treatments for apple-orchard soils must involve a properly balanced and complete fertilizer

treatment, and the maintenance of organic matter which aids in the conservation of moisture in the soil.

Studies of Fruit Varieties.—Since the establishment of this experiment station workers in the horticultural department have given attention to the question of varieties of fruits for the several fruit growing sections of the state. This study is being conducted at Blacksburg and observations are made from year to year in the fruit-growing regions of the state on the behavior, adaptation and value of varieties of apples, peaches, grapes and other fruits. Their value for home garden purposes, as well as their commercial possibilities are taken into account. A useful store of information has been developed from variety studies which is drawn upon constantly for the guidance of fruit growers in the state.

Local Orchard Management Experiments.—Investigations bearing upon soil management, fertilizer applications, and in some cases pruning and spraying are being conducted at Winchester, Appomattox and in several orchards in the vicinity of Blacksburg. Comparison is being made between fall and spring applications of nitrogenous fertilizer, and tests are being made of different fertilizer materials, singly and in combination, in several orchards. The object of this work is to obtain facts and information of practical value to fruit growers.

Experiments were made in the Gittens orchard near Salem to determine the effects of applying nitrogenous fertilizer to Stayman Winesap apple trees at different seasons of the year. The trials were conducted for three years. Annual applications of 3.2 pounds of sulphate of ammonia were applied to each tree in March; other plats received like applications in April, May, June, July, and August, respectively. For comparison, an annual application of 4 pounds of nitrate of soda was applied to each tree in another plat in March; and still another plat, which served as a check, received no fertilizer. In every instance, the average yield of fruit per tree was increased by the nitrogenous fertilizer, regardless of the time it was applied. The average annual yield per tree from the plats which received sulphate of ammonia, regardless of the time it was applied, exceeded the average annual yield per tree from the plat treated with nitrate of soda in March; however, the latter exceeded the average annual yield of the trees on the check plat by about 66 per cent.

In the analysis of data to compare the effects of applying a nitrogenous fertilizer all at one time as against a split application, the results of an experiment with York Imperial apple trees in the Round Hill orchard near Winchester showed the following: Yield records over a 6-year period were secured from 144 apple trees 20 years old, 72 of which received a dosage of sodium nitrate in March and 72 of which received one-half of this dosage in March and the other half in June. These trees, in a strikingly uniform portion of the orchard, were blocked off into 6 pairs of plats, 2 pairs receiving 4 pounds,

2 pairs 7 pounds, and 2 pairs 10 pounds of sodium nitrate per tree in single and split dosages. The average annual yields per tree over this 6-year period are as follows: 267 pounds for the single against 348 pounds for the split in one 4-pound pair; 239 pounds for the single against 379 pounds for the split in another 4-pound pair; 236 pounds for the single against 321 pounds for the split in one 7-pound pair; 331 pounds for a single against 427 pounds for a split in another 7-pound pair; 301 pounds for a single against 370 pounds for a split in a 10-pound pair; and 357 pounds for a single against 402 pounds for the split in the other 10-pound pair.

Computations made by either Bessel's or Student's formula show significant increases of the split applications over the single. With splitting showing a gain of 86 pounds or about a bushel and a half of apples to the tree, it will be left to the apple grower whether or not he cares to go to the additional trouble of making such applications. The expense for this additional labor should be very small as compared to a probable gain of a bushel and a half of apples if his is a typical orchard in Virginia.

In the fall and spring nitrogenous fertilizer experiment a block of 16-year-old York Imperial apple trees near Blacksburg in the Apperson orchard was secured. Each treatment was confined to a row of 24 trees. Comparisons in response to different treatments were made within pairs of trees of approximately the same circumference and topography and differences calculated by the use of Student's method. These comparisons were made for terminal growth and yields covering a 3-year average, starting with the season following the first applications.

For the trees in the rows receiving 2 pounds of sodium nitrate in the spring, there was an annual average terminal growth of 5.5 inches as against 5.9 inches for the same amount applied in the fall. This, however, is not a significant difference if computed by Student's method. A significant difference shows up in favor of the 4-pound fall application with 7 inches of terminal growth as compared to the same amount applied in the spring, which showed only 5.9 inches growth. The yield records do not provide such definite differences. They are, nevertheless, of interest and will, therefore, be presented. The annual average yield per tree for the 2-pound fall application is 254 pounds as against 172 pounds for the same amount applied in the spring. The trees in the 4-pound fall application row showed an average annual yield of 207 pounds as compared to 225 pounds for the same amount applied in the spring. The differences would not be considered mathematically significant. However, if growth and yield responses are taken together, the chances favor the fall applications. This statement, however, should be supported by more experimental evidence.

Paper Cartons for Apple Packages.—Experiments extending over a period of four years have shown that the paper carton is a satisfactory package

for marketing apples. It appears to have practical application under some conditions, and is likely to be used more extensively in the future, since it is a relatively cheap package and well suited for urban apartment needs.

Breeding Apples.—Crosses were made between Stayman Winesap, Grimes, York Imperial and Yellow Newton apples, and the seedlings derived from these crosses are being observed as to their value and possible uses.

Grape Breeding.—Crosses were made of Vinifera and Bourquiniana with Labrusca and other American species. Selections are being made from these seedlings with a view of finding desirable recombination types. Selections are also being made from seedlings of Concord, Delaware, Eumalan and Niagara.

Japanese Millet as a Cover Crop in Apple Orchards.—This study has been in progress several years and it appears that under certain conditions Japanese millet is a very desirable cover crop to use in apple orchards.

DEPARTMENT OF DAIRY HUSBANDRY

The station work in dairy husbandry is in charge of Professor C. W. Holdaway, dairy husbandman, and he is assisted by Mr. A. D. Pratt, assistant dairy husbandman. Professor W. D. Saunders is conducting investigations dealing with cheese making.

The dairy husbandry department and the department of agricultural chemistry cooperate in the cow feeding project which is one of the principal lines of investigation. Several other projects of importance to the dairy industry in Virginia are also being studied, including pasture improvement, the value of succulent dairy feeds, and milk processing.

Protein and Energy Requirements for Milk Production.—There are several separate phases of this investigation dealing with the effects of minimum and maximum amounts of protein on the efficiency of the feeds, on milk production, and on the health of animals; the amounts of protein and energy necessary in producing uniform quality and varying amounts of milk; the relative value of the proteins of different forage crops, grains and by-products in producing milk; and the amounts of protein necessary for growth of young animals. Special attention is given to studies of feeds which are grown in this state.

A feeding trial was made with dried apple pomace, which is available in quantity at vinegar plants in the fruit growing regions of this state. The results of this study were reported in Technical Bulletin No. 32, and it was shown that dried apple pomace was a satisfactory substitute for dried beet pulp in the ration of dairy cows.

Another phase of this investigation was concerned with methods of balancing rations for dairy cows in digestibility trials with corn meal. The results of this study were published in Technical Bulletin No. 38. It was

found that the addition of corn meal to the ration widens the protein-energy ratio, which, if not offset by the necessary amount of high protein feed, will depress the digestibility of the protein in the whole ration. Another feeding trial was run with Hevea rubber seed meal as the source of protein in the ration of dairy cows. This material is a by-product from the processing of the kernels of Para rubber seed, which are imported in quantity and processed at Norfolk for the purpose of extracting the oil which is used in the paint industry. The pulp which remains after the processing contains 30 to 33 per cent of crude protein, and in this feeding trial it was found that Hevea rubber seed meal is a very satisfactory protein concentrate in rations for dairy cows.

Feeding trials are being conducted with alfalfa and timothy hays as sources of protein and minerals in feeding dairy cows. It is a cooperative project between this department and the Bureau of Dairy Industry of the U. S. Department of Agriculture. The results up to the present time favor alfalfa hay from the standpoint of milk production. The groups of cows receiving alfalfa hay have uniformly sustained milk production better than the group of cows receiving timothy hay, there being a difference of 16 per cent more milk from the cows fed alfalfa hay. Digestion trial balances show but slight variations in the digestibility of the protein in the two kinds of hay. The excess of calcium in the alfalfa hay, which is about three times the amount fed in the timothy hay rations, has apparently affected the retention of calcium by the animals and the balances are greater than during the periods when the same animals were fed timothy hay.

Pasture Experiments.—In 1930, experiments were undertaken for the purpose of studying the effects of fertilizers and lime on bluegrass pasture, the effects being measured by the amount of milk produced by cows on the pasture lots that are being compared. Four pasture areas, consisting of 10 acres each, of which two received fertilizer treatments and two were unfertilized, were laid out for these experiments. Lot 1 was limed and 1,000 pounds of 8-8-8 fertilizer was applied per acre. The nitrogen was supplied in the form of sulphate of ammonia, which was applied one-half in April and one-half in July. One ton of ground limestone was applied per acre. Lot 2 was fertilized and limed in exactly the same way, but was subdivided into three equal sub-

Table 11.—Results of pasture experiment to June 1, 1931

	Fertilized		Unfertilized	
	Lot 1 Unrotated	Lot 2 Rotated	Lot 3 Rotated	Lot 4 Unrotated
Cow days, number	651	688	227	209
Milk produced, pounds	17,587	15,334	3,320	2,935
Fat produced, pounds	649	552	124	115
Equivalent in 4 per cent milk, pounds	16,770	14,421	3,190	2,900
Gain in weight, pounds	341	777	569	438

lots for the purpose of rotating the animals on the pasture. Lot 4, which was unfertilized, was rotated also. The application of fertilizer produced 1.7 times the pasturage, 1.7 times the amount of milk and 1.6 times the total digestible nutrients that were produced on the check lot. Table 11 shows results of the pasture experiments to June 1, 1931.

Succulence Project.—Most dairymen are including a succulent feed in the dairy ration as a routine practice. In some seasons, such as the drought year of 1930, it is very expensive to provide succulent feed for the dairy cow. Beet pulp is the best available substitute for corn silage, but normally our dairymen depend upon corn silage for their succulent feed. The limited supply of beet pulp causes the price to be too high in proportion to its actual feeding value. This experiment which was recently undertaken is designed to find out in what way succulent feeds are beneficial in increasing the production of milk.

Milk Processing.—Many of the metals used for the making of dairy processing machinery are known to be soluble in milk to a slight degree at the temperature used in pasteurizing milk. It is known that traces of these metals are not injurious and in some cases are even beneficial to animals. Manganese is one of these metals. The object of this experiment is to determine whether manganese in milk during the pasteurization process will destroy the vitamins of milk.

Cheese Investigation.—This project, which is in charge of Professor W. D. Saunders, deals with two questions: (1) Standardization of milk for cheese making; and (2) the manufacture of cheese from high acid milk.

The standardization of milk for cheese making has been receiving attention all over the country in recent years. The object is to equalize the content of butterfat and casein in the milk so as to produce cheese of uniform composition. The experiments showed that with the removal of the right amount of butterfat the cheese would carry approximately 50 per cent of butterfat in the dry matter, and 40 per cent of moisture, which will soon dry out to an extent that will leave the moisture content 39 per cent, which is the amount required by law.

The making of cheese from milk containing a relatively high per cent of acid has been a troublesome problem for all cheese makers. Formerly it was considered that milk containing 0.20 per cent acid was unsuitable for cheese making. Professor Saunders developed a method by which milk containing as much as 0.35 per cent of acid could be made into a satisfactory, marketable cheese. The method is to add water to the cheese vat immediately after the curd is cut, and then reduce the acid in the whey to 0.10 per cent or less, depending on the amount of acid originally in the milk. The cooking is done at a temperature not above 100°F. (98 to 100) and the curd is allowed to lie in the whey about two hours, or until the acid in the whey has risen to about

0.18 per cent. This method has been applied successfully under factory conditions, as well as in the experimental tests.

DEPARTMENT OF ANIMAL HUSBANDRY

After the death of C. R. Nobles, assistant animal husbandman, in August, 1928, Professor R. E. Hunt, animal husbandman, took charge of the station work in this department, which is concerned with hog feeding experiments, supplemental feeds for steers on bluegrass pasture, the improvement of bluegrass pasture on which heavy cattle are grazing, and methods of managing the beef cow herd.

Hog Feeding.—One phase of this experiment, which was carried out at the substation near Williamsburg, showed that pasture crops could be used to a certain extent in reducing the cost of producing pork. Such crops as soybeans, corn and peanuts were hogged down in a satisfactory way.

Another phase of the hog feeding work deals with the effects of certain feeds on the quality of the pork produced, and this study is being made in cooperation with the U. S. Department of Agriculture and with several state experiment stations. It is known that peanuts and soybeans, when fed to hogs, produce what is known as soft pork, and the object of this study is to find out what methods of feeding and management will enable the farmers to overcome this problem. It was found that the addition of cottonseed meal to the ration of hogs which had been fed for a part of the fattening period on peanuts had a tendency to harden the pork, and 70 per cent of the hogs so fed produced satisfactory carcasses. Our department of home economics is also cooperating in this study by making cooking tests on the pork produced in this experiment.

In 1930 thirty-six pigs were used in the experiment and they were fed in four lots of nine pigs each by a self-feeder method on rations which were made up of the constituents and proportions shown in Table 12 for the number of days indicated.

Table 12.—Constituents and proportions of the rations

	Lot 1		Lot 2		Lot 3	Lot 4
	36 days	62 days	36 days	62 days	98 days	98 days
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Peanuts, shelled and ground	82.7	--------	82.7	--------	--------	90.0
Wheat middlings	5.0	--------	5.0	--------	--------	--------
Tankage	5.0	5.0	5.0	5.0	9.0	9.0
Alfalfa leaf meal	5.0	5.0	5.0	5.0	5.0	5.0
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Ground limestone	1.0	1.0	1.0	1.0	1.0	1.0
Steamed bone meal	1.0	1.0	1.0	1.0	1.0	1.0
Ground white corn	--------	73.0	--------	80.0	90.0	--------
Cottonseed meal	--------	21.0	--------	14.0	--------	--------

At the end of 14 weeks the hogs with an average weight of 222 pounds each were shipped to the government abattoir at Beltsville, Maryland, where they were slaughtered and the carcasses graded for firmness. The amount of feed consumed, and the total gains for each lot are shown in Table 13.

Table 13.—Feed consumed and gain in weight

	Feed consumed	Gain in weight
	Pounds	*Pounds*
Lot 1	6025	1319
Lot 2	5962	1215
Lot 3	6141	1130
Lot 4	5980	1347

Hogs which received peanuts in their ration made the greatest gain, but the carcasses graded softer than was the case in other lots. After representative samples of hams and loins from each hog were cooked, the judges who scored them as to quality and palatability placed the peanut samples as high or higher than the corn fed samples. It is suggested that perhaps the best way to deal with the so-called soft pork problem is to devise methods of cooking the pork which will make it attractive and palatable. Peanut-fed hogs in particular produce pork which has an attractive flavor, although the fat in the pork has a lower melting point than the fat in pork produced by corn feeding.

Supplemental Concentrated Feeds for Cattle on Bluegrass Pasture.—This study is being made in cooperation with the U. S. Department of Agriculture. Steers and spayed heifers were kept on bluegrass pasture during the summer of 1930. They were divided into four lots of eight animals each. Three lots received supplemental rations of cottonseed meal and corn, while the fourth lot received no supplemental feed. At the end of the grazing season it was found that the additional gains in weight made by the animals receiving supplemental feeds, as compared to the gains of the animals on bluegrass pasture alone, were not sufficient to pay for the cost of the supplemental feeds. Since supplemental feeding of beef cattle on bluegrass pasture did not pay in the drought summer of 1930, it does not seem probable that this method can be profitably employed in normal years when pastures are much better than they were in 1930. However, this study will be conducted for another year or two.

Improving Pastures.—Investigations were begun in the spring of 1930 to find out whether it is economical to improve bluegrass pastures in Southwest Virginia on which heavy cattle are grazed. Many pasture areas in this section have been grazed continuously for 50 years or more without the addition of any fertilizer to such pastures.

Seven lots of 15 acres each were fenced in Smyth County in Rich Valley on typical bluegrass pasture land. Running water was available in each lot.

These lots were treated as follows: Lot 1 received an application of 300 pounds of 16 per cent acid phosphate per acre. Lot 2 received 2,000 pounds of lime per acre. Lot 3 received 300 pounds of 16 per cent acid phosphate, 100 pounds of muriate of potash and 200 pounds of ammonium sulphate per acre. Lot 4 received 100 pounds of muriate of potash and 300 pounds of 16 per cent acid phosphate per acre. Lot 5 received 300 pounds of 16 per cent acid phosphate, 100 pounds of muriate of potash and 200 pounds of ammonium sulphate per acre; and in addition, 2,000 pounds of lime per acre. Lot 6 received 300 pounds of 16 per cent acid phosphate and 2,000 pounds of lime per acre. Lot 7 was used as a check or control area to which no fertilizer was applied. Owing to the extreme drought of 1930 the applications of fertilizers, as measured by the gain in weight of cattle on these lots, did not produce any results. However, the growth of bluegrass on the fertilized plats in the spring and early summer of 1931 indicates very important effects from the fertilizer treatments. During this season it will be possible to judge more accurately the value of fertilizer treatment for bluegrass pasture in this area. Present indications favor the complete fertilizer and lime treatment, but it remains to be seen whether this is the most economical method of improving bluegrass pastures.

Management of Beef Cow Herd.—This project is designed to secure data on the various items concerned in the management of the beef cow herd, and particularly to find out the costs and returns from the raising of beef calves for either feeders or baby beef. In the spring of 1930 forty grade Hereford heifers which were 2 years old were purchased. These heifers were all bred and raised in Southwest Virginia, and they were in thrifty condition and weighed approximately 750 pounds each when purchased. They were pastured during the summer of 1930 on a farm 7 miles northeast of Blacksburg; and a purebred Hereford bull and a purebred Angus bull ran in the pasture with the heifers. The heifers were wintered on a ration consisting of 20 pounds of corn silage and 2 pounds of cottonseed meal each per day, and on April 20, 1931, they were turned out to pasture. The calves came in March and April of 1931. During the summer the calves were left with their dams, and part of the calves were supplied concentrated feeds in addition to the pasture and the milk of their mothers.

DEPARTMENT OF ZOOLOGY AND ANIMAL PATHOLOGY

The station's work in this department is in charge of Dr. I. D. Wilson, head of the department, and he is assisted by Dr. E. P. Johnson, assistant animal pathologist, who succeeded Dr. R. A. Runnells on September 1, 1930, and by Dr. L. E. Starr, assistant animal pathologist. The investigations in this department deal with diseases of poultry and diseases of other livestock, which are important from the standpoint of livestock farming in this state.

Pullorum Disease of Fowls.—This disease is one of the most troublesome of all the diseases with which poultrymen have to contend. At the time our studies were undertaken the pullorum disease was causing severe losses to poultry farmers, as well as to hatcheries and to poultry breeders. Our investigations on this disease extended over a period of several years. Experiments were conducted dealing with the effects of pullorum infection on chicks and on adult hens. Also the effects of the infection on fertility and hatchability of eggs were considered. The experiments brought to light methods for handling this disease, and showed how infection might be avoided by blood testing of the fowls and by segregation of infected birds from the clean stock. Our Bulletin No. 265 describes these experiments, and the conclusions which came from them. In connection with this study Dr. Runnells discovered that the rapid method agglutination test after suitable modification could be applied effectively for the diagnosis of pullorum disease in fowls. This application of the rapid method reduced by one-half the cost of testing birds, and dispensed with the necessity of sending the blood samples to the laboratory for test, because the rapid method can be used effectively at the poultry farms.

Contagious Abortion in Cattle.—This disease has come to be important in all sections of the country. Studies on it were begun in 1928, and the investigation is being conducted by Dr. L. E. Starr. Efforts are being made to differentiate actively infected animals, immune animals and negative animals, by means of the blood test. The animals are grouped and segregated in two or three classes, according to their reaction to the blood test. The animals being used in the investigation are the college dairy herd, the experiment station dairy herd, the college beef herd and several dairy herds out in the state. The animals are tested regularly, and segregated according to their reactions to the blood test. Bacteriological examination of the milk from all the infected and immune cows is made to determine whether the cows are throwing off the causative organism in their milk. It is not correct to state that the segregation program is a thoroughly effective method for handling this disease; however, it is the best method known at the present time. Approximately 550 animals have been used in this investigation.

Special studies are being made on the transmission of the organism which causes this disease, and the method by which it enters the animal. Inocculations were made by infecting the eye and skin of rabbits, calves and swine. This feature of the experiment will be completed in the fall of 1931.

Bovine Coccidiosis.—This disease is common in calves in southwestern Virginia, the principal symptom of which is described as black or bloody diarrhea. Because of the economic importance of this disease Dr. Wilson began an investigation of it in the fall of 1928. The disease was found on many farms and examination showed that the disease was caused by coccidia. In some cases parasites in the lungs were associated with coccidiosis, but these

are separate problems. The experiments on bovine coccidiosis were carried out extensively, and the results published in Technical Bulletin No. 42. At least three species of coccidia are responsible for this disease, including *Eimeria zurnii, Eimeria smithi* and *Eimeria cylindrica,* the latter being a new species described for the first time in this bulletin.

Fowl Paralysis.—The fowl paralysis problem in the state is becoming more acute each year. Only a few years ago this disease was rarely met with in Virginia, but at the present time it is rather wdespread in the state, and is the cause of serious losses in poultry flocks. Since its cause and mode of transmission are not yet known, methods for combating it are unsatisfactory. Investigations were undertaken to determine whether the disease is transmitted from adult fowls to chicks.

Vaccine Against Chicken-Pox.—It has been found that pigeon-pox virus produces a high degree of immunity and is not followed by the severe systemic reactions, nor the decrease in egg production noticed after the use of chicken-pox virus as vaccine.

DEPARTMENT OF AGRONOMY

The research in agronomy covers a wide range of topics, including crop production, breeding and selection for the purpose of improving varieties of farm crops, fertilizer experiments and crop rotations. Professor T. B. Hutcheson, head of the department of agronomy, has charge of the station work in this department, and other members of the staff are Dr. N. A. Pettinger, associate agronomist; M. S. Kipps, assistant agronomist; G. W. Patteson, agronomist in charge of the soil survey project; and Edward Shulkcum, assistant agronomist, in the soil survey project.

Factors Influencing Growth and Maturity of Corn.—The phase of this study which is now receiving special attention is concerned with the chemical composition of the sap of corn plants as an indicator of the deficiency of plant food elements in the soil. The sap is expressed with a small hydraulic press which gives pressures above 10,000 pounds per square inch. Corn plants were available from plats which had received particular fertilizer treatments, extending over a long period of time. In addition to this material corn plants were grown in sand cultures to which nutrient solutions in known proportions were added.

A problem was encountered in making nitrate nitrogen determinations in the sap of corn plants by reason of the fact that a satisfactory method was not available for clarifying the sap solution. H. H. Hill, of our chemical department, devised a satisfactory method for clarifying the sap of corn plants which overcame this problem.

Progress on this investigation was very satisfactory. In 1930, the results of this study were set forth in an article submitted to the Journal of Agricultural Research entitled, "The Expressed Sap of Corn Plants as an Indicator of Nutrient Needs." Dr. N. A. Pettinger is the author of this article, and it will appear in an early number of the Journal. Some of the important conclusions from this study are here briefly stated. There is a general relationship between the color of the expressed sap and the productiveness of the soil on which the plants were grown. After clarification, colorless saps and those of a light shade of brown indicate a fertile soil, while a dark brown color in the sap is associated with unproductiveness. Color characteristics of sap were associated with the abundance or deficiency of nitrogen, potassium and phosphorous. The hydrogen-ion concentration of the sap of corn plants is not appreciably correlated with soil productivity, although it shows a fair correlation with potassium fertilizers.

Cereal Investigations

These investigations deal with the improvement by breeding and selection of corn, wheat, oats, rye and barley.

Corn Breeding and Selection.—The cross between Boone County White and Silver King continues to give higher yields of grain than either parent variety. Table 14 gives the average results for a period of ten years. The cross matures sufficiently early to escape frost in the higher altitudes of southwestern Virginia.

Table 14.—Average yield per acre of grain and stover from Boone County White and Silver King, and from a cross between them for the years 1921 to 1930, inclusive

Variety or cross	Grain	Marketable grain	Stover
	Bushels	*Per cent*	*Tons*
Boone County White	42.66	75.81	2.07
Silver King	40.52	83.83	.85
Cross	48.70	83.99	1.03

An effort is being made to determine whether corn can be improved by inbreeding for only one year and then re-combining the desirable inbreds into one strain. Another study deals with the fixing of the sun-red color in the cross between Boone County White and Silver King. The value of the inbreeding method as a means of producing a superior type of corn is being tested.

Wheat.—The selections V. P. I. No. 131 and V. P. I. No. 112 continue to show superiority over other varieties of wheat. Surveys by county agents, and reports from seedsmen, indicate that from 25 to 50 per cent of the wheat grown in Virginia is of these two varieties, which were developed at this sta-

tion. Other wheat selections which have not yet been distributed to farmers are being grown in increase plats, and some of them are promising. Comparative yields on the experimental plats at Blacksburg are shown in Table 15.

Table 15.—Average yearly yields per acre of two leading varieties of wheat in comparison with selections for the years 1920 to 1930, inclusive

Variety or selection	Yield
	Bushels
Fulcaster	18.59
Fultz	19.83
V. P. I. No. 112	20.12
V. P. I. No. 130	22.94
V. P. I. No. 131	21.36
V. P. I. No. 136	21.53
V. P. I. No. 164	22.25
Selection A	20.07
Selection D	20.71
Selection E	23.00

Oats.—V. P. I. No. 1, developed in 1919, is being tested every year and it continues to give satisfactory results in our trials as well as on farms out in the state.

Barley.—Twenty selections of barley have been made and are being tested as to yield and other characteristics, in comparison with Tennessee Winter and other varieties of barley. Four of the selections yielded over 40 bushels per acre in 1930.

Rye.—Variety tests of rye are made annually.

Forage Crops

Investigations are under way dealing with varieties, breeding, and cultural practices. The crops included are soybeans, red clover, sweet clover, lespedeza, and orchard grass.

Table 16.—Average annual yield of seed per acre from soybean selections compared with the parent varieties for five years

Variety	Yield
BLACK EYEBROW SELECTIONS	*Bushels*
Selection No. 63	17.66
Selection No. 154	14.07
Selection No. 178	14.64
Selection No. 269	17.20
Black Eyebrow	16.66
VIRGINIA SELECTIONS	
Selection No. 118	15.07
Selection No. 188	16.08
Selection No. 337	16.46
Selection No. 453	14.00
Virginia	13.59

Soybeans.—Selections of several promising strains have been made from the Virginia and Black Eyebrow varieties. Their average yields per acre for the years 1925 to 1929, inclusive, in comparisan with the Black Eyebrow variety, are shown in Table 16. An experiment on inoculating soybean seed at the time of planting has not shown positive results, compared with uninoculated seed.

Red Clover.—Trials of red clover seed from different localities proved conclusively the superiority of certain domestic strains over strains of red clover from foreign countries, particularly in the ability of domestic strains to resist the anthracnose disease. Lots of red clover seed were secured from 35 localities in foreign countries, and from 27 localities in the United States, and these seeds were grown on plats here at the station. The imported sorts were not able to withstand the attacks of anthracnose. Seed for these tests were furnished by the U. S. Department of Agriculture.

Sweet Clover.—A comparison was made in the sowing of unhulled and scarified seed of biennial white sweet clover for hay production. The results were in favor of unhulled seed. It appears that the difference is due to the effects of alternate freezing and thawing of the soil which injures the scarified seed but does not harm the unhulled seed. Best results were secured from sowing sweet clover in January and February.

Lespedeza.—Two selected strains of native lespedeza are being tested as to their value for pasture. One strain came from the top of Price Mountain and the other from the Shenandoah Valley. Both produced satisfactory pasture, although neither yields as much vegetation as the Kobe or Korean varieties.

Orchard Grass.—Selection and breeding experiments are being conducted, and a number of promising strains are receiving further tests and are being inbred. Individual plants in these selections are far better than the commercial types of orchard grass commonly used on the farms.

Other Investigations in Agronomy

Fiber Plants.—A study of the growing of hemp for seed production was begun in 1926 in cooperation with the U. S. Department of Agriculture. Seven improved strains of hemp are grown in isolated plats. The object is to find out whether the production of hemp seed is practicable in this region, and also to improve the seed producing strains.

Tests are being made at Blacksburg, and at the county stations, on the possibilities of producing flax for fiber purposes. These experiments have given yields varying from 1,500 pounds to 6,000 pounds of cured flax straw with seed per acre per cutting. They indicate that on lands capable of producing fifty bushels of corn to the acre an average yield of 2 tons of flax per acre may be reasonably expected. Two seedings per year of flax may be made

on the same land—one in early spring and one in mid-summer. However, the summer seedings rarely yield more than half as much as the spring seedings.

Pasture Experiments.—This investigation deals with the effects of heavy applications of nitrogenous fertilizer on bluegrass pasture, and the object is to find out to what extent fertilizers can be used economically to increase the growth of vegetation on the land and to what extent the chemical composition of the plants is influenced by the application of fertilizer. The department of agricultural chemistry cooperates in this study and the results of the pasture experiments are reported under that department.

Rotation and Fertilizer Experiments.—The rotation experiments with the application of certain kinds and amounts of fertilizer have been in progress for 21 years. The plats are located on Hagerstown silt loam soil. The rotation is corn, wheat, clover and grass, which is a 4-year rotation. The best average results were obtained from applications of stable manure. There was no significant difference between a 16-ton application of manure once in four years, and an annual application of 4 tons of stable manure. Results almost as good were secured from the application of complete fertilizer to crops.

An experiment on inoculation of the clover seed used in these experiments showed only slight increase in hay production as compared to uninoculated seed.

Continuous Cropping.—The object of this experiment is to study the effects of continuous growth of the same crop on the land with and without application of fertilizer. The results for 16 years show that the plats which were treated annually with 16 tons of manure and 219 pounds of floats per acre have given fair yields of corn, wheat and grass, whereas yields from the check, or untreated plats, were very low. The results are shown in Table 17.

Table 17.—Average annual yields under continuous cropping

Crop	Fertilized plats	Check plats
Corn annually, bushels per acre	35.64	18.93
Wheat annually, bushels per acre	19.80	9.93
Grass continuously, tons per acre	2.04	1.06
Grass reseeded every two years, tons per acre	2.10	1.21

Phosphate and Sulphur Experiment.—The purpose of this experiment is to compare superphosphate, raw rock phosphate, basic slag and bone meal as sources of phosphorus; and manure, nitrate of soda, dried blood and ammonium sulphate as sources of nitrogen in a corn, wheat, and clover rotation. In this experiment calcium sulphate has been added to all phosphate carriers, except superphosphate, equivalent to the amount of the calcium sulphate in the superphosphate used. The object was to determine whether the superior results usually obtained from superphosphate could be attributed to sulphur.

No beneficial results have as yet been obtained from sulphur applications. Superphosphate has shown slightly better results than phosphorus from other sources, both in heavy and light applications. Manure has given best results as a nitrogen carrier with nitrate of soda the best of the commercial nitrogen carriers used. However, yields have been uniformly good for all of the mixtures with only slight differences in the results.

Fertilizer Application.—The purpose of this experiment is to determine the proper place in a corn, wheat and clover rotation to apply superphosphate and manure. The results indicate that there is little difference in results to be obtained from small annual applications and larger applications less often.

Superphosphate Experiment.—The object of this experiment is to determine what quantities of 16 per cent superphosphate can be applied economically per acre on Hagerstown silt loam soil for the production of certain crops. The treatments given and the average annual yield of crops from the plats are shown in Table 18, for the years 1920 to 1930, inclusive. The results of this trial are not striking, and further trials are needed to find out what may be expected from the application of different amounts of superphosphate to these crops.

Table 18.—Comparison of the effects of different quantities of 16 per cent superphosphate on Hagerstown silt loam soil for eleven years for corn, wheat and hay production

Treatment per acre	Corn	Wheat	Hay
	Bushels	*Bushels*	*Tons*
100 lbs. 16 per cent superphosphate	42.41	17.17	1.48
200 lbs. 16 per cent superphosphate	38.45	16.59	1.79
Check. No fertilizer	35.38	14.33	1.68
300 lbs. superphosphate	41.13	17.84	1.71
400 lbs. superphosphate	42.87	18.55	1.86
Check. No fertilizer	41.81	16.11	1.74
500 lbs. superphosphate	44.57	20.54	1.95

Lime Experiments.—Extensive trials are being made comparing burnt lime and ground limestone in different quantities per acre on Hagerstown silt loam soil on which corn, wheat, clover and grass are grown. These trials have been running for 12 years. Comparable results are secured from burnt lime and ground limestone when used in equivalent quantities, and the evidence seems to favor the application of smaller quantities of lime than those formerly recommended.

Trials of ground limestone, burnt lime, marl and precipitated marl for a period of 15 years (1916-1930, inclusive) have been made. Table 19 sets forth the results which are substantially alike, as shown by the crop yields from these trial plats. The lime materials were applied at five-year intervals in the quantities stated in the table.

Table 19.—Average annual yields of corn, clover, grass and soybean hay per acre when different forms of lime are applied to the soil, for a period of fifteen years

Treatment per acre	Corn	Wheat	Clover hay	Grass (hay)	Soybean hay
	Bushels	*Bushels*	*Tons*	*Tons*	*Tons*
2 tons ground limestone	50.86	14.34	2.77	2.71	1.78
1 ton burnt lime	49.31	13.06	2.31	2.13	1.64
Check. No lime applied	46.20	12.26	1.67	1.91	1.38
2 tons marl	52.20	13.64	2.48	2.52	1.73
2 tons precipitated marl	50.14	15.02	2.52	2.83	1.74

Potato Selections.—Variety tests of potatoes have been made for a number of years and selections of promising strains from the varieties Bliss Triumph and Green Mountain show superior yielding capacity under local conditions. Comparative yields of the selections and parent varieties are shown in Table 20.

Table 20.—Average annual yields per acre of selections and parent varieties of potatoes for the years 1924 to 1930, inclusive

Variety or selection	Yield
BLISS TRIUMPH AND SELECTIONS	*Bushels*
Bliss Triumph	35.31
Selection No. 287 (Tech. Triumph)	67.63
Selection No. 317	42.33
GREEN MOUNTAIN AND SELECTIONS	
Green Mountain	70.02
Selection No. 106	84.22
Selection No. 308	91.76

Potato Seed Experiment.—This experiment was planned to determine the practicability of growing seed potatoes in Southwest Virginia for the early potato crop in eastern Virginia. During the period of this experiment, the yields of potatoes, especially seed stock, were very low. And as the period progressed, the yield of seed tubers diminished. As to the dates of planting, the plantings made on April 1 at Blacksburg, and on May 1 at Burke's Garden produced better yields than earlier or later plantings at either of the two localities. From the results of yields of potatoes in the Southwest Virginia trials and from the behavior of the seed when planted at the Virginia Truck Experiment Station at Norfolk in comparison with northern-grown seed, it appears that seed potatoes grown in Southwest Virginia cannot successfully compete with northern-grown seed in the eastern Virginia potato district.

The Soil Survey

In 1904 the Bureau of Soils of the U. S. Department of Agriculture began to make surveys of the soils in two small areas in Virginia, and this work was

conducted for a number of years without material assistance from the state. About 15 years ago the Federal Department of Agriculture adopted a policy of conducting soil surveys only in states which were in a position to cooperate to the extent of defraying approximately one-half of the expenses of the survey, and due to the fact that funds were not available for this purpose in Virginia little work was done on this project after the year 1918.

The Commission [1] to Study the Condition of the Farmers of Virginia made its report to the General Assembly of Virginia in January, 1930, and among other important items recommended, "that the soil survey of the state be completed as soon as possible in order to obtain an inventory of our soil resources and to determine the adaptability of our lands to various crops, forestry and livestock enterprises." The General Assembly considered this recommendation favorably and enacted a law providing for the continuance of the soil survey to be made under the direction and supervision of the Agricultural Experiment Station at the V. P. I. in cooperation with the U. S. Department of Agriculture, and appropriated $7,500.00 for the fiscal year beginning July 1, 1930 and $7,500.00 for the fiscal year beginning July 1, 1931, for defraying the expenses of the soil survey.

The Experiment Station made plans promptly for undertaking the survey, and employed two men who began work on July 1, 1930. At the same time the Federal Department of Agriculture sent two experienced soil surveyors to Virginia to work in cooperation with the state men. The work was organized in soil survey parties with one Federal employee and one state employee in each party. G. W. Patteson and R. E. Devereux began the survey work in Grayson County. R. C. Jurney and Edward Shulkcum began the soil survey work in Rockbridge County. During the winter months while the weather conditions were unfavorable for surveying in the greater portion of the state, a survey party was sent to Nansemond County, in southeastern Virginia, where weather conditions were favorable for field work nearly all the winter.

Satisfactory progress was made in the soil survey project during this fiscal year. The survey of Grayson County was completed. The area of this county is 425 square miles. A report containing 55 typewritten pages was prepared to accompany the soil map of Grayson County, and was submitted to the editorial staff of the Bureau of Chemistry and Soils of the U. S. Department of Agriculture. The survey of Grayson County describes and gives

---

[1] The Commission was created by an Act of the General Assembly of Virginia of 1928, which authorized the appointment of the Commission and prescribed the powers and duties of said Commission. It was provided that the membership of the Commission should consist of two members from the Senate of Virginia, two members from the House of Delegates and six members to be appointed by the Governor. The following persons served on the Commission: Senator S. J. Thompson, Pounding Mill; Senator J. B. Watkins, Midlothian; Hon. W. Stuart Moffett, Staunton; Hon. A. J. Terrell, New Canton; Hon. F. K. Whitehead, Roseland: Dr. Julian A. Burruss, Blacksburg; Hon. R. Warren Fuqua, Prospect; Mr. G. F. Holsinger, McGaheysville; Prof. T. C. Johnson, Norfolk; Mr. J. V. Nichols, Purcellville; Mr. Edward G. Tankard, Nassawaddox. The Commission elected Dr. Julian A. Burruss chairman. The Commission made its report to the General Assembly of Virginia in January, 1930.

the location on the map of the several types of soil in this county, and observations regarding the adaptation of different types of soil to agricultural purposes. The soils best suited to pasture supported the most prosperous livestock farms. Livestock was found to contribute at least 75 per cent of the gross income of farmers in this county. Observations were made on the fertilizer and lime requirements of soils in the area. The relations of soil types to forestry were pointed out.

Rockbridge County has an area of 600 square miles, and at the end of this fiscal year 75 per cent of the area of this county had been surveyed, and it is expected that the work will be completed in Rockbridge County on or before October 1, 1931.

On June 20, 1930, soil survey work was begun in Augusta County, which is a large county, containing over 1,000 square miles. The survey in this county will scarcely be completed by June 30, 1932. We expect to complete the survey in Nansemond County during the winter of 1931-1932. This county has an area of 425 square miles and about 260 square miles of its area were surveyed in the winter of 1930-1931.

In the soil survey work special attention is given to the relationship between crops and soils. The reports on the soil surveys give special attention to this point and furnish valuable information for the guidance of farmers and others interested in farm lands in connection with the fitting of farming enterprises to soil types. This information is fundamental to the development of the agricultural resources of the state.

The force and facilities available for soil surveying are entirely inadequate. Provision should be made for two more soil survey parties, one of which should be provided by the state and the other by the Federal Government. Provision should be made for a chemist to analyze the several types of soil which occur in the areas that are being surveyed. There should be available a laboratory and necessary equipment for doing chemical work in soils and for properly storing soil samples.

There is wide demand for soil survey work in many counties in Virginia, and requests have come to us from agricultural leaders, business organizations, chambers of commerce, and from hundreds of farmers requesting the experiment station to begin soil surveys in particular counties. In view of the wide demand for this service it is hoped that the General Assembly may find it possible to provide larger funds for carrying on this work. The Bureau of Chemistry and Soils of the U. S. Department of Agriculture expects to be in a position to meet any increase made by the State Government on a 50-50 basis.

DEPARTMENT OF AGRICULTURAL ENGINEERING

The experiments and investigations in farm power and machinery in this department were handled by D. C. Heitshu, assistant agricultural engineer, until he resigned on July 31, 1930. Professor P. B. Potter, associate agricultural engineer, began investigations on two projects in the field of household engineering on July 1, 1930. Professor J. W. Sjogren, assistant agricultural engineer, who succeeded Mr. Heitshu on October 1, 1930, continued the investigations dealing with farm power and machinery problems.

Tractor Cultivation of Row Crops.—Trials of the rotary hoe for the cultivation of corn indicated that the rotary hoe was adapted to the earlier cultivations of corn because it moved rapidly and damaged the plants no more than does the ordinary row cultivator. The hoes should be sufficiently spaced to prevent the wedging of stones or sticks between the hoes. Further trials of the old style malleable iron rotary hoe and of the new flexible-frame, steel hoe were made in 1931 in the cultivation of corn. These machines were coupled into a 4-row unit and were used together so that the conditions of operation would be the same. The hoes were used in a field of corn containing old tree stumps. The old style rigid-frame hoe passed over the stumps with greater ease than did the flexible-frame hoe, but in doing so left more land untilled. The flexible-frame, steel hoe adapts itself more easily to the irregularities of topography. The damage to the crop was small with either hoe. Best work is done with the hoes operated at a speed of three miles per hour.

Plowing Tests.—Discs for plowing were tested in 1928. A field was divided into five plats, and each plat was plowed with a different type of plow. The plows used were as follows: (1) Moldboard; (2) disc; (3) "Wheatland" one way plowing disc; (4) "Big Bill" plowing disc; and (5) "Pulverator." The plowing was done in a corn stubble field of rolling topography. The condition of the soil was reasonably uniform throughout, and the tests were therefore comparable. The results are shown in Table 21.

Table 21.—Plowing tests

Plow	Plowing depth	Plowing time per acre	Fuel factor (per acre basis)	Discings required for good seed bed
	Inches	*Hours*	*Relative*	*Number*
Moldboard	8	1.53	1.0	2
Disc	7½	1.6	1.03	2
Wheatland	6½	1.1	0.663	4
Big Bill	5	0.91	0.655	4
Pulverator	8	2.28	1.26	0

These data indicate that the "Wheatland" and "Big Bill" types of plow are not desirable for the conditions here described, where deep plowing is required for corn. The "Pulverator" was very satisfactory for this purpose.

Combine Harvesting.—Tests were made on the combine for harvesting small grain and soybeans under Virginia conditions. The combine has been used successfully in the grain growing regions of the West and it seemed desirable to test it out under Virginia conditions, which differ particularly as to climate. The study was made in cooperation with the U. S. Department of Agriculture. The combine harvested rye and wheat satisfactorily at a total cost of $3.10 per acre, which is a saving of about $1.50 per acre over the usual binder and thresher method. Of course, many factors will naturally be considered, but the individual farmer has to know whether his acreage is sufficient and the topography of his land suitable for using a combine economically. Care must be exercised in properly drying the grain after it comes from the combine. Bins were constructed out of doors with suitable ventilation for drying grain threshed by the combine.

The tests of the combine in harvesting soybeans of several varieties showed that the combine was satisfactory for this purpose, and gave an average loss of only 11½ per cent of the seed, as compared to a loss of about 35 per cent when soybeans are harvested with row harvesters or cut with a mower. The following mechanical features have been found desirable to adapt the combine to Virginia conditions for harvesting soybeans: (1) A flexible or floating cutting-bar capable of cutting within four inches of the ground; (2) the cylinder speed should be reduced to 450 or 500 revolutions per minute to prevent excessive splitting of beans; (3) the separating mechanism should be kept at normal speed.

General Purpose Tractor.—A study was made to find the fundamental requirements of the general purpose tractor, and the results of this study were published in Agricultural Engineering in May of 1929. The most important features include the following items: (1) The tractor should be equipped with a steering mechanism that will give the operator ease as well as precision of control; (2) lateral stability is essential and is obtained by having the engine mounted as low as possible and still maintain ample clearance between the tractor frame and the soil; (3) adaptability to a wide range of rows; (4) comfort and safety of the tractor operator.

The general purpose tractor was tested in the cultivation of corn, potatoes and other crops. Desirable features of a tractor cultivator include the following items: (1) Flexibility in both lateral and longitudinal directions for successful operation on rolling, hilly, terraced, and irrigated land; (2) easily attached to and detached from tractor; (3) provision for cultivating tractor-wheel tracks; (4) ability to control tractor and cultivator with steering gear alone; (5) ability to lift cultivator with one lever.

A special study is being made relative to the problem of stability in the tractor. A device was arranged for weighing tractors as a basis for calculating the center of gravity. These data are needed in order to study the influence

of topography on the stability of traction machinery under standard loads and given soil conditions.

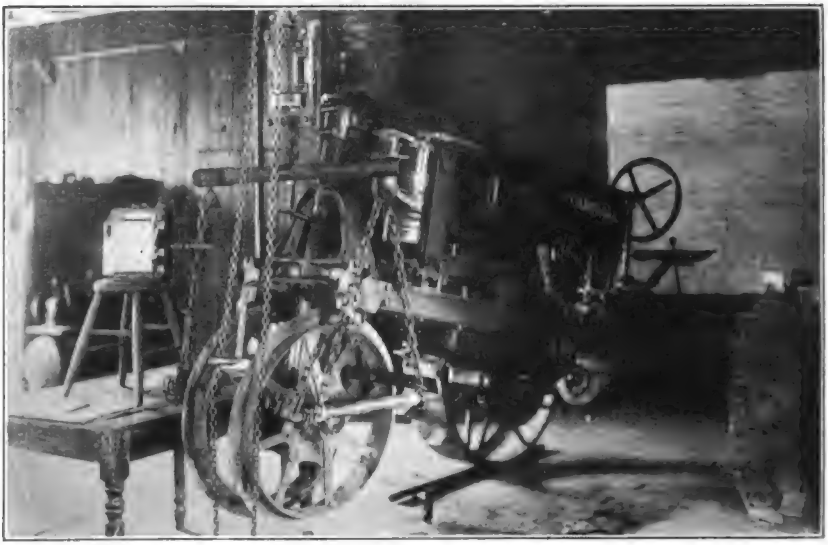


Fig. 6.—Showing the use of traction dynamometer in weighing the front end of a tractor

Household Engineering.—Two lines of investigations have been undertaken in this field, including home laundry investigations and reliability tests of oven regulators. It is expected that several phases of these two studies will be gone into. A laboratory has been fitted up in the basement of the Agricultural Hall, and equipment is being gradually installed for the investigations on these subjects. The study of home laundering is a part of the general subject of household cleaning. The object of this study is to evaluate the factors involved in washing clothes at home. Among these factors are the water used, its hardness and temperature; the soap used, its kind, cost and amount; and the machine used, its type, capacity and time required. The inter-relationships of these factors will be considered. It is expected that ten or a dozen of the more prominent washing machines on the market will be tried out in this investigation. The machines are used in accordance with instructions furnished by the manufacturers. For clothes, sheets, half-sheets and quarter-sheets, made up in 4-yard, 2-yard and 1-yard sizes, are used in the machines as filler or load. Into each washing are placed six samples of cloth, each 1 foot square and dosed with a definite amount of standard dirt. At the end of five-minute periods the samples are withdrawn and then rinsed and dried, ready for reading. These samples are read in a special Bunsen photometer to determine their relative light reflection, by which means the cleanliness coefficient is

determined. The results are not yet conclusive, but some very definite trends have been indicated in the experiment. It was found that temperature has a very important effect. Very much better results are obtained when the temterature of the wash water is from 140° to 160° and 170° F. At these temperatures the cleaning continues longer and is quicker. It appears that about 50 per cent of the cleaning is done in the first five minutes of time, and what is done after that comes more slowly in the last fifteen minutes. The washing was not continued longer than thirty minutes.

Equipment was assembled for the oven regulator tests, including electrical range thermocouples and electrical pyrometer. The object of this study is to devise accurate and reliable regulators for ovens. It is well known that oven regulators vary greatly, and it is important to find out why this is so. There is also the question as to how necessary it is to maintain accurate temperature in cooking, and possibly there is not a need for highly accurate instruments in regulating the temperature.

Hot Water Heating Studies.—The importance of having hot water for clothes washing is being definitely shown by our own home laundry tests. Hot water is equally necessary in many other household processes. The water heating apparatus of the home is as important as any other equipment. Therefore is seems pertinent to acquire up-to-date information on this subject. The new methods of heating water automatically with electricity especially need investigation for more exact information. Accordingly, an experiment was begun in June with the idea of finding out the characteristics of electrical heating of water. This work was begun with an ordinary 30-gallon bare range boiler tank and 2,000-watt "side-arm" heater with thermostat, this outfit representing an adaptation of electrical heating to apparatus already in use in the home. Extensive tests were carried on all summer with this set-up to show its capacity for heating, the amount of energy required, ability to maintain temperature, rate of cooling or heat loss, and general over-all efficiency. The bare tank was tested, the tank with wool felt jacket, and the tank with 1-inch asbestos plaster. Results show conclusively that this outfit will heat water in amounts and with top temperatures sufficient for household requirements. Over-all efficiency is not high and it is easily seen that the complete units now on the market are far ahead of this installation in efficiency. The cost of electricity for heating water is higher than for any other energy but with rates for current constantly being reduced and with any kind of value being given to the automatic, care free features, electricity can compete with other forms of energy.

One particular outstanding result is the value of insulation on the tank. In the ordinary operation of the outfit fully 50 per cent of the energy can be saved by proper insulation. Putting it in figures a ready-made asbestos or felt jacket costing from $5.00 to $7.00 would pay for itself four times over

each year. The higher the temperature maintained in the tank the more the cost and the greater value the insulation has. The thermostat is highly important for service and economy. The test on this phase of electrical heating was completed this summer. It is to be followed by similar complete tests on the manufactured units with inside submerged heater and heavy insulation. Electrical heating of water is just one phase of the ultimate project which is to include all fuels, all features of the installation, such as insulation, temperatures, costs, size of storage, compact outfits, automatic devices, and so forth. Electrical heating will be complete in itself but only a part of the whole matter of heating water.

Electric Iron Tests.—As an important part of our home laundry investigations the subject of electric iron characteristics was taken up last May because an opportunity and request for such work was furnished by Sears Roebuck & Company. Tests were started on some fifteen or more of the leading irons on the market in both the old type and the new automatic types. The object here is to find out the operating characteristics, the costs of operating, the value of automatic controls and the lasting qualities of the different irons. The work is now about two-thirds completed, but the life tests of 500 hours on each iron will require a considerable period of time, but not much labor, in the latter phase of the tests. First results on the irons show uniformity in sizes, weights and current consumption of the irons. There is considerable variance in the heating ability and maintenance of temperature. The automatic controls show conclusively their value in the safe and economical heating of the iron. The automatic irons cannot get too hot and burn up. Their current consumption is much less when controlled.

In the actual ironing tests some of the irons are showing considerable falling off in temperatures maintained and ability to heat up in a satisfactory way. This results in complaint of the operator. It shows also that the standard 600-watt irons fall short of satisfaction and that the new 1,000-watt irons are produced because of a need for more reserve ability to heat in certain grades of ironing. There is a hint that thermostats of certain types will fail to last the life of the iron while in another type of thermostat very little deterioration can occur. We believe this to be fundamental information if the life-tests can be carried on long enough. Some study is being made of the effect of amount of moisture (dampening) in the clothes on the speed and cost of ironing. This project is to be practically complete this fall with a technical report available to manufacturers and a popular report available to the public. We believe it will be a worth while contribution to the general study of household appliances.

Experiments with various other kinds of home equipment are needed and should be taken up as soon as funds and personnel are available for expanding the work in this department.

DEPARTMENT OF AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

Research in agricultural economics was begun in 1923 in response to a wide demand for station services in this field. For a part of the time covered by this report Professor J. J. Vernon had charge of the station's work in agricultural economics. When Dr. C. C. Taylor was appointed head of the consolidated department of agricultural economics and rural sociology he had general supervision over all the investigations in the department, and handled personally one or two of the projects in this department. After his resignation in November, 1930, Dr. H. N. Young was placed in charge of the work. Other members of the scientific staff are Dr. Roy A. Ballinger, associate agricultural economist; J. L. Maxton, assistant agricultural economist; Chas. J. Blair, Jr., assistant agricultural economist; and Paul L. Fletcher, assistant agricultural economist.

Research in rural sociology was started in 1925. Dr. W. E. Garnett, rural sociologist, Professor B. L. Hummel, rural sociologist, and C. H. Hamilton, assistant rural sociologist, conduct the investigations in rural sociology. The progress of the investigations in the two divisions of this department will be presented separately.

Agricultural Economics

A wide variety of problems in the field of agricultural economics were dealt with during the period of time covered by this report, chief among which were marketing apples, dairy farm management and marketing of milk, historic study of prices of farm products in Virginia, taxation, adapting farm operations to market demands, economics of strawberry production, marketing beef cattle, economics of early potato production, stock share renting, marketing woodland products, marketing tobacco, marketing wool, and local farm management studies.

Economics of Apple Production and Marketing.—Several separate studies were made bearing upon this topic. The first study was concerned with the factors influencing the yield of apples in the Cumberland-Shenandoah region, and it was made in cooperation with the U. S. Department of Agriculture and with the stations in Pennsylvania and West Virginia. The study took into account the characteristics of orchards in this region, and the various factors which influence yield, such as frost, hail, drought, topography, soils and orchard practices. The results of this study were published in Technical Bulletin No. 54, which was issued by the U. S. Department of Agriculture in December, 1927.

Another study, likewise cooperative with the agencies mentioned in the preceding paragraph, was concerned with the marketing of apples grown in the Cumberland-Shenandoah region. Marketing outlets were described and it was shown that heavy supplies of apples increased the difficulties of marketing, while normal storage facilities aided in orderly marketing. Some varieties of apples sell better than others, and market preferences of certain varieties were found to exist. Grading was an important factor in the price received. The results of this cooperative study were published in Technical Bulletin No. 234, issued by the U. S. Department of Agriculture in March, 1931.

Still another cooperative study in the same region deals with the place of the orchard in the farm organization. Detailed records are being made on orchards in Virginia, West Virginia and Pennsylvania. Records for the third year will be completed in 1931, and they will show the various items of cost in growing apples, as well as the place which the apple orchard holds in the farm organization.

Dairy Farm Management and Marketing Milk.—A study was made of the market for milk in Richmond, in which the U. S. Department of Agriculture cooperated. The territory supplying milk to the Richmond market was surveyed and dairying conditions in the territory were described. The trend of milk production and consumption of milk and milk products was studied. It was found that Richmond consumed one-half pint of milk per capita per day, whereas New York City consumes three-fourths pint of milk per capita per day. The results of this investigation were published in Bulletin No. 263.

A study was made of systems of dairy farm management for the Richmond milk producing area, in cooperation with the U. S. Department of Agriculture. J. L. Maxton was located in Richmond for three years, and conducted a detailed study of dairy farm management on a limited number of dairy farms, each of which were visited twice a month in order to obtain complete records of every important item in the cost of the dairy enterprise and the other enterprises which contributed to the dairy business on the farm. The results of this study were published in our Bulletin No. 272, issued in June, 1930. It is suggested, on the basis of records of successful dairymen in this region, that many dairy farms could be reorganized so as to handle the business more efficiently, and suggested systems of organization are described.

A study was made of the marketing of fluid milk in the cities of Newport News, Petersburg, Lynchburg and Bristol. Producer-distributors handle a considerable portion of the milk consumed in these cities. It was pointed out in this study that dealer-distributors or producer-cooperatives might effect economies, standardize the production and stabilize the price more effectively than can the individual producers who distribute their milk directly to consumers. The results of this study were published in Bulletin No. 275, issued in December, 1930.

Prices of Farm Products.—An historical study was made of the prices received by producers of farm products in Virginia from 1801 to 1927, the station and the U. S. Department of Agriculture cooperating in the study. In order to obtain the data it was necessary to consult files of newspapers, agricultural journals, account books of millers, merchants and farmers, and other sources of information. Complete series of prices were constructed for the principal farm products of Virginia, including wheat, corn, oats, rye, apples, strawberries, potatoes, sweet potatoes, tobacco, cotton, peanuts, beef cattle, feeder cattle, hogs, bacon, sheep, lambs, wool, milk cows, milk, butter, chickens, eggs, horses and mules. The results of this study were published in our Technical Bulletin No. 37, which was issued in March, 1929, and contains 218 pages, 123 tables and 46 figures. This publication is a valuable source of information for research workers in agricultural economics, for extension workers, for teachers of agriculture and for farm leaders who must deal with the problem of guiding agricultural production.

Taxation.—The subject of taxation has assumed great importance from the standpoint of farmers in recent years, and there are frequent calls for the facts connected with taxation. The station investigated taxes on farm and urban real estate in cooperation with the U. S. Department of Agriculture, and with the University of Virginia. It was found that more than half of all direct taxes paid by farmers in Virginia are real estate taxes. Farm real estate taxes absorbed 20 per cent of the net rent of 1,093 farms for which data were secured for the year 1926. Taxes on urban real estate absorbed 16 per cent of the net rent of 889 pieces of urban property in 1926. Urban taxes therefore were only 80 per cent as high as farm taxes. The results secured in this study are described in detail in Bulletin No. 268, issued in September, 1929.

Under another station project a study was made of the tax system of Virginia. This study was completed in June, 1931, and a bulletin will appear shortly giving the results of this study. The tax laws of the state were briefly described, as well as the subjects of taxation and the revenue yielded from different taxes.

A study has been undertaken of the problem of farm real estate assessments in Virginia.

Making the Most of Local Markets.—When distributing costs are relatively high it is a matter of importance for farmers to utilize fully the markets in nearby towns and cities. In this connection a study was made in the territory surrounding Covington and Clifton Forge to find out possible adjustments which farmers there might make by way of adapting their production to meet the needs of consumers in those cities. The results of this study were published in Bulletin No. 266, which was issued in April, 1929. The U. S. Department of Agriculture cooperated with the station in this project.

Strawberry Production.—The U. S. Department of Agriculture in 1928 was engaged in an investigation of the factors which affect returns received by strawberry growers in the principal strawberry producing areas of this country. Members of the station staff cooperated in this investigation, and assisted in assembling data on the problems in the strawberry region of Virginia.

Marketing Beef Cattle.—Representatives of the U. S. Department of Agriculture investigated the economic factors affecting the beef industry in Virginia, and two members of the station staff collaborated in certain features of the investigation. The results of the investigation were published in Technical Bulletin No. 237, issued in 1931, by the U. S. Department of Agriculture. It was shown that marketing problems are closely related to production problems, that beef cattle raisers in Southwest Virginia need to give more attention to the quality of cattle and that they should market younger cattle in response to consumer demand for smaller cattle.

Another project deals with the marketing costs of livestock and wool. This study has not been completed, but interesting results are appearing which will be published at some later date.

Stock Share Renting.—Stock share renting is not practiced extensively in Virginia at the present time, but there are important possibilities in it and a study of this question was made in cooperation with the U. S. Department of Agriculture to ascertain the current practices in connection with stock share renting. The most common practice met with was for the landlord and tenant to own each one-half of the livestock and receive one-half of all sales. The expenses are also divided half and half, except the labor and machinery, which are furnished by the tenant, and the land and buildings, which are furnished and kept in repair by the landlord. The results of this study were published in Bulletin No. 271, which was issued in May, 1930. In this bulletin suggestions were made as to the items which should be included in the stock share leasing agreement.

Marketing Woodland Products.—Over 50 per cent of the forest land of Virginia is within the boundaries of units designated and operated as farms, and the marketing of forest products from these units is an important phase of the farm problem. In order to render service to the farmers in connection with this problem a study was made of the marketing of woodland products in cooperation with the department of wood technology of the Virginia Polytechnic Institute. Methods of selling timber, and markets were canvassed. Practices connected with estimating and measuring timber were studied and costs of harvesting and marketing the several classes and kinds of timber in the state were studied. The results of this investigation were reported in Bulletin No. 276, which was issued in December, 1930.

Other Studies in Agricultural Economics.—In addition to the studies previously mentioned in this report several other projects are being conducted, as indicated by the following project titles:

Cost of Production and Profits under the Systems of Farming in the Potato-Growing Areas of Virginia, in cooperation with the U. S. Department of Agriculture.

Marketing Virginia Tobacco: A study of markets, methods, costs and prices.

A Study of Farm Organization and Management in Grayson County, in Cooperation with the U. S. Department of Agriculture.

An Economic Study of Poultry Farming in Virginia.

An Economic Study of Farmers' Cooperative Purchasing and Selling Organizations, in cooperation with the Federal Farm Board.

A Study of Economic and Social Conditions in the Mountainous Areas of Virginia, in cooperation with the U. S. Department of Agriculture, and several state experiment stations.

Rural Sociology

The investigations in rural sociology have centered around rural organizations and factors which influence the attitudes of farmers toward organizations. Among the subjects studied in this field since our investigations in rural sociology were begun are the following: Rural organizations in relation to rural life, with particular reference to attitudes of farmers toward organizations; young peoples' organizations; community organization and development; the rural church situation. The progress and results of research in rural sociology are described in the paragraphs which follow.

The Rural Church.—Because of the important place which the rural church holds in the life of farm people, and especially its relations to organizational effort, it seemed highly desirable to make a study of the relation of the rural church to rural community welfare. Country life is now undergoing profound changes, involving readjustments in many directions. Some rural churches are aiding, while others are retarding these readjustments. For these reasons the rural church problem is a matter of serious concern to all agencies charged with the responsibility of promoting various types of country life programs. The study was primarily concerned with the community relations of the rural church, but other factors were also taken into account. The church proper, the Sunday school, and young peoples' religious organizations were studied intensively, and the study included both white and Negro churches. Both the favorable conditions and tendencies, as well as the unfavorable conditions and tendencies were pointed out. Constructive suggestions were made for improving the program of rural churches and for increas-

ing the services of the rural church to its community. The results of this study were published in Bulletin No. 267, issued in June, 1929. Another phase of the church study dealing with the Negro church in rural Virginia was reported in Bulletin No. 273, issued in June, 1930. In the latter publication the special problems of the Negro rural church were dealt with and suggestions and recommendations were made, looking toward improvement in the program of work and in the service which the Negro rural church renders.

Young Peoples' Organizations.—For several years a study of young peoples' organizations has been in progress. Special attention was given to vocational organizations, such as the 4-H club and voluntary clubs associated with the agricultural departments of high schools. The results of this study were published in Bulletin No. 274, issued in June, 1930. It was found that the greater majority of Virginia rural youth are not yet receiving needed specialized country life training. Both the 4-H club organization, and the organization connected with the agricultural departments of high schools are doing useful and effective work, although there is opportunity for improvement in both of these undertakings, and suggestions are made for improving the programs and for extending the benefits of these organizations for young people to larger numbers of rural people. A supplementary study on the effects of club work on school work was made by Miss Stubbs, professor of sociology in State Teachers College at Farmville, and published as section 4 of Bulletin No. 274, in which Professor Stubbs showed that positive and significant values are contributed to the education of the children by 4-H club work, and that since an informal cooperation between the schools and clubs had produced significant results a definite and purposeful program of integration of school and club work would likely result in greater educational values.

Applications of Research in this Field.—The study made in connection with rural organizations in Virginia has produced practical results in the following ways. There are a large number of rural organizations in Virginia and formerly these organizations functioned independently. Through suggestions made in our publications and through efforts of members of the staff in rural sociology, and of course through many other agencies, the formation of the Agricultural Conference Board was accomplished. The Conference Board is a representative body which brings together in a united way all of the principal farm organizations in Virginia. This is considered an important accomplishment in which the station work and workers in rural sociology had a large part.

The Rural Church Survey has been the basis for many denominational reports and programs. The study of the rural church situation brought out the need for inter-denominational organizations to deal with needed adjustments in rural church work in the state. As a result of our study, the interest of forward-looking church leaders, and the direct efforts of members of the

staff in the department of rural sociology, the Rural Church Conference Board supported by leaders of eight denominations was formed. Its program includes an annual conference; an annual ten-day school for rural ministers held at the V. P. I.; and efforts for the observance by all churches of an annual Rural Life Day program. The latter has in it great possibilities for promoting a more intelligent interest in rural life problems. Without doubt there is a useful field for the Conference Board, since there are many ways in which it can serve rural church groups throughout the state.

The study of young people's organizations has quickened efforts for more effective work in this important field.

Other Studies in Rural Sociology.—Several other important projects are being studied in the rural social field. The most important of these are as follows: A study of the attitudes of rural people toward organizational policies and problems, together with the reasons for prevailing attitudes; community development trends; and studies in rural community development. There is pressing need for investigations along several other lines dealing with numerous problems in the field of rural sociology, and these investigations will be made as soon as the station's resources will permit.

DEPARTMENT OF HOME ECONOMICS

After the resignation of Dr. Ellen A. Reynolds, home economist, on October 7, 1927, Miss Ilena M. Bailey was appointed home economist on the station staff, and she conducted the research in home economics during the rest of the time covered by this report. Investigations are under way dealing with several problems of interest and importance to home makers in Virginia.

Home Living Standards.—Miss Bailey served on a committee with Miss Martha Dinwiddie in preparing, in 1928, a report on the condition of farm homes in Virginia. Data on which the conclusions were based were collected from a number of authorities in particular lines and were interpreted with great care in the light of personal knowledge. This study brought out the low average income of farm families in Virginia compared with that of city families, and the small amount of money available for important items in the budget of the farm families. Not only does the income of farm families need to be increased, but the increased income needs to be built into better living standards by wise expenditures. The study points out many lines in which extension teaching needs to be increased, and the lack of information which is needed as a basis for the intelligent development of such teaching services. Much of this needed information lies in the field of social and economic problems of the home. Hence, the report emphasizes the need for expansion of the station's research program in agricultural economics, home economics and rural sociology.

Food Expenditures and Dietary Standards.—The study was concerned with the kind, quantity and cost of food for 74 rural families, or nearly 500 persons. The average number of persons fed in these households was equivalent to 5.5 adult male units and the cost per man per year was $126 or about $700 per family. The cost per man is lower than that found in studies made in several other states but the cost per family is higher. This is because of the larger size of the families in Virginia and also because about 80 per cent of the food here is furnished by the farm, which makes it cost less than if purchased at a village or city store. The quantity of food consumed is adequate in amount but is lacking in sufficient fruits and vegetables and proportionately in iron. Although the data were not analyzed by seasons this deficiency is undoubtedly greatest in the winter months when fresh fruits and vegetables are not easily obtained by farm families.

Rural Housing.—An extensive study was made of rural housing and records were obtained from 255 white families and 195 colored families. Nearly one-half of the families, white and colored, had not lived in their present houses over five years, while only 8 to 9 per cent had lived there over 25 years. Such frequent changes increase the cost of living, affect house planning and furnishing, and retard the installation of modern equipment and the development of attractive rural home surroundings. Although Virginia has been settled over 300 years only 2 per cent of the houses of white families in this sample, which is typical of conditions in the valley and central section of the state, were over 100 years old and only 13 per cent had been built over 50 years. Just 4 per cent of the homes occupied by negroes had been built over 50 years. Nearly 60 per cent of the houses of white families and 70 per cent of those of negro families were not more than 20 years old. These last per cents are similar to those obtained in a study made recently in Arkansas and indicate that a number of new houses are being built each year. Thus an opportunity is afforded to improve housing gradually but further studies are needed on other phases of housing in order that more information will be available for the use of prospective home owners and extension workers. All of the houses were classified according to a score card into three groups. Of those occupied by white families 28 per cent were excellent or good and 25 per cent were poor or very poor, while only 4 per cent of the negro houses were in the first class and 46 per cent were included in the latter. Room overcrowding as measured by the number of bedrooms per person exists to a large extent. One-half of the white families have more than two persons per bedroom. There were 6 per cent who had from 5 to 8 persons sleeping in the same room. The per cents were about the same for negro families. In some instances there is overcrowding because of few rooms being heated rather than because of small houses. Information was obtained also on ownership, state of repair, conveniences, amount of ventilation and sunlight, and health of the family.

Rural Family Living—Grayson County.—In June, 1931, a study of the content, adequacy and conditioning factors in the standard of living of rural families in Grayson County was undertaken in cooperation with the Bureau of Home Economics and the Bureau of Agricultural Economics of the U. S. Department of Agriculture, and the department of agricultural economics of this station. Several temporary field assistants were employed to aid in securing field data. About 350 rural families will be studied in this area. Through this cooperative arrangement data were obtained on the total amount and the sources of the income available for family living and also the kind, quantity, and value of food furnished by the farm as well as wild products gathered. Data were also collected on the kind, quantity, and value of food and clothing purchased, the amount spent by the family for health, advancement and personal items, the size of families supported on the income, the education of all members of the family, the occupation and location of sons and daughters who have left home, the kind of work done by women and children and the extent to which they help with farm work, the burden of indebtedness, purchasing practices of the families, and the type of homes they can afford as measured by value, age, material, condition, and equipment. Although not yet tabulated and analyzed the reports of the field assistants and the checking of the records indicate that much definite information has been obtained which will show the progress being made in education and roads in this mountain county, as well as the handicaps in the woeful lack of these facilities in some parts of the county. It is already known that a number of families have very little contact with persons outside of their small communities even through papers, magazines, books or radio. When completed, the report will form the basis for the development of effective and much needed home extension work as well as furnish valuable information of use to the departments of education, public health, the state traveling library, and other agencies in the state and the county. Another study is planned along the same line, to include about 170 families in the early potato region on the Eastern Shore of Virginia.

Cooking Soft Pork.—A laboratory was equipped for cooking pork in a cooperative project with the department of animal husbandry. This study is also a part of a large national cooperative project dealing with quality and palatability in meat. There is a question whether pork produced by the feeding of peanuts and other crops which tend to give soft pork is as valuable as corn-fed pork. No doubt the question of consumer tastes and preferences comes into play here. Smithfield hams and shoulders, also hams and loins from hogs fed peanuts and from hogs fattened on corn, are being used in this study. Several factors will be considered, including cured cuts, cooking, use of the fat, effects of storage temperature, ageing, and effects of rations fed to the hogs.

DEPARTMENT OF POULTRY HUSBANDRY

Poultry is raised on nearly every farm in Virginia, and on many farms poultry is the principal source of income. There has been wide demand for station service on poultry problems. Seven years ago the station initiated investigations on certain poultry disease problems, and the investigations were made by staff members in the department of zoology and animal pathology. In 1928 the station cooperated with the V. P. I. department of poultry husbandry in a poultry feeding project, and on July 1, 1929, Dr. Reece L. Bryant was appointed assistant poultry husbandman on the station staff for part of his time, and he has continued the feeding experiments and undertaken other investigations on several important poultry problems.

Peanut Meal as a Source of Protein for Chicks.—The object of this study was to determine whether peanut meal could be substituted for meat scrap in whole or in part as a source of protein in the ration of chicks. Four feeding trials were made, beginning when the chicks were one day old and continuing for eight weeks. The chicks were fed in six lots, usually of 100 chicks each, and the rations were arranged to compare the results when different proportions of peanut meal were substituted for corresponding proportions of meat scrap in the ration. This phase of the study was completed in 1931, and will be published in Bulletin No. 281 early in the fiscal year of 1931-1932. The important findings in this experiment were as follows: (1) Peanut meal supplemented with minerals can be used to replace at least 50 per cent of the meat scrap in starting rations without affecting growth, mortality or feed consumption, and at present ratios between the cost of peanut meal and meat scrap a cheaper feed will result; (2) where more than 50 per cent of the meat scrap is replaced with an equivalent amount of the meal, growth of the chicks is less rapid; (3) rations with peanut meal alone as the source of protein are not palatable and produce slow growth of the chicks.

Another phase of this study deals with the use of peanut meal as a source of protein in the ration of laying hens. It was begun in October, 1930, using 125 Barred Rock pullets which were divided into five lots of 25 birds each. The rations are made up so as to draw a comparison of results when peanut meal is substituted for meat scrap in several proportions. At the end of six months the results indicated that peanut meal could be substituted for some portion of the meat scrap in the ration of laying hens without decreasing egg production and without injury to the quality of the eggs.

Pigmentation in Chicks Reared in Battery Brooders.—One factor that seems to be a great drawback to the production of broilers by battery brooder methods is the lack of pigmentation of shanks and beaks. In an attempt to find means of correcting this condition an experiment was undertaken in February, 1931, using 250 day-old Barred Plymouth Rock chicks

which were divided into five lots of 50 chicks each and placed in a battery brooder. The object is to determine whether lack of pigmentation can be corrected by the kind of feeds supplied the chicks. Since it is known that green feeds have a tendency to produce pigmentation, it was decided to test alfalfa leaf meal as a substitute for green feed in the ration of chicks that are being reared in a battery brooder. To a normal ration was added varying percentages of alfalfa leaf meal. The first feeding trial extended over a period of eight weeks and the results indicate that the addition of alfalfa leaf meal to the ration of chicks reared in the battery brooder does increase the pigmentation of shanks and beaks without affecting the growth of the birds. Several other feeding trials will be made before this study is concluded.

Mazda CX Lamp as a Source of Ultra-Violet Rays for Poultry.—It is claimed that Mazda CX lamp produces sufficient ultra-violet rays to protect chicks from rickets. If this claim is substantiated the use of such a lamp will undoubtedly be more economical than the feeding of cod-liver oil as a preventive of rickets. An experiment was undertaken to test this lamp on several lots of chicks, using other lots for comparison which received cod-liver oil in the ration. This experiment has not been concluded, but at the end of eight weeks there were no symptoms of rickets in either the cod-liver oil lots or the lots subjected to rays of the Mazda CX lamp. While a check lot which received neither treatment showed nearly 100 per cent of the chicks affected with rickets.

Need for Expanding Poultry Investigations.—There is considerable demand from poultrymen in the state for additional service from the station in connection with various poultry problems. At the earliest moment possible there should be provision for increasing the scientific staff in the poultry husbandry department, and there should be provision also for more funds to secure needed labor, structures and scientific equipment in connection with poultry investigations.

THE COUNTY STATIONS

Experiments and investigations dealing with local farming problems are conducted at eight substations which we have usually designated as county experiment stations. Professor T. B. Hutcheson, agronomist, supervises the investigations at the county stations. There is a superintendent located at each county station who has immediate charge of the work, as follows: B. G. Anderson, superintendent of the Appomattox County station; R. P. Cocke, superintendent of the James City County station; W. W. Green, superintendent of the Caroline County station; T. L. Copley, superintendent of the Pittsylvania County station; E. T. Batten, superintendent of the Nansemond County station; P. T. Gish, superintendent of the Augusta County station; H. C. Marshall, superintendent of the Charlotte County station; and W. R. Perkins,

superintendent of the Washington County station. The progress of investigations at each of the county stations will now be described.

Appomattox County Station

This station is located near Appomattox Court House, and the investigations at this station deal mainly with dark fire-cured tobacco, and other crops commonly grown on dark tobacco farms.

Fertilizers for Dark Tobacco.—Soil conditions at this station are quite similar to those which prevail throughout dark tobacco growing sections of Virginia. The common practice in this region is to grow tobacco in a rotation with wheat and red clover. The plan of this experiment is as follows: The tobacco on the plats is followed by wheat and red clover. Each plat is limed at the rate of 1,000 pounds of burnt lime to the acre before seeding the clover. All other fertilizer is applied before the tobacco is planted. This experiment is the principal project at the Appomattox station, and it has been running in the present form for 11 consecutive years. The object of this experiment is to study the effects of different combinations of nitrogen, phosphoric acid and potash on the production of dark tobacco, taking into account both the pounds of tobacco produced per acre and the quality as shown by the selling price. Table 22 shows the kind and amount of fertilizer applied per acre to the several plats in this experiment, and the average annual yield and the annual average value of the tobacco on each plat for the years 1920 to 1930, inclusive. It will be noted that the method was to apply on one plat 100 pounds of ammonia, 100 pounds of potash and 100 pounds of phosphoric acid to the acre. In the succeeding four plats the potash was reduced at the rate of 20 pounds per acre until the sixth plat was reached, which received no potash.

Table 22.—Varying the fertilizer constituents for dark tobacco at Appomattox, 1920 to 1930, inclusive

Plat No.	Kind of fertilizer and amount applied per acre			11-year averages	
	Ammonia	Phosphoric acid	Potash	Yield	Value
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Dollars*
1	100	100	100	935	143.40
2	100	100	80	917	135.60
3	100	100	60	889	130.15
4	100	100	40	878	133.68
5	100	100	20	875	127.80
6	100	100	---	897	124.80
7	100	80	100	940	141.82
8	100	60	100	960	145.10
9	100	40	100	906	127.72
10	100	20	100	859	126.10
11	100	---	100	892	109.56
12	80	100	100	915	138.18
13	60	100	100	907	132.02
14	40	100	100	944	128.48
15	20	100	100	842	109.23
16	---	100	100	795	94.85

Likewise, ammonia and phosphoric acid were applied in diminishing amounts until the plat is reached where neither is applied. This method affords an opportunity to study the effects of each fertilizer constituent on the production of dark tobacco. The phosphoric acid was obtained from 16 per cent acid phosphate, the potash from sulphate of potash and the ammonia was obtained one-third from dried blood, one-third from tankage and one-third from nitrate of soda. From the data extending over a period of 11 years, it appears that the best combination of fertilizer for dark tobacco on this type of soil is 80 to 100 pounds of ammonia, 80 to 100 pounds of phosphoric acid and 80 to 100 pounds of potash per acre.

The results of experiments conducted at this station indicate that high grade complete fertilizers supplied in relatively heavy application for dark tobacco are more profitable than lighter applications. Many of the tobacco growers in this region are using 4-12-4 and 4-16-4 analysis on their tobacco crops with good results. Even fertilizer of still higher analysis is being experimented with by tobacco growers.

Experiments extending over a period of 11 years have been made for the purpose of comparing the relative merits of ammonia derived from different sources and potash derived from different sources in the production of dark tobacco. The results of these trials are shown in Table 23, which shows the kind and quantity of fertilizers applied to the plats, and the average yield and average value of the tobacco produced for a period of 11 years. The results indicate that dried blood, an organic carrier of nitrogen, is superior to either nitrate of soda or sulphate of ammonia for dark tobacco production. The results also indicate that it is desirable to secure part of the nitrogen from an organic carrier and part of it from an inorganic carrier. The results indicate that it makes little difference whether potash in dark tobacco fertilizer

Table 23.—Incomplete and complete fertilizers for dark tobacco at Appomattox, 1920 to 1930, inclusive

Plat No.	Kind of fertilizer and amount applied per acre	11-year averages	
		Yield	Value
		Pounds	*Dollars*
1	800 lbs. 16% acid phosphate	740	84.27
2	625 lbs. dried blood, 800 lbs. 16% acid phosphate	899	124.20
3	189 lbs. dried blood, 454 lbs. tankage, 136 lbs. nitrate of soda, 800 lbs. 16% acid phosphate	937	140.12
4	Check. No fertilizer	540	55.45
5	550 lbs. nitrate of soda, 800 lbs. 16% acid phosphate	801	96.86
6	400 lbs. sulphate of ammonia, 800 lbs. 16% acid phosphate	832	100.48
7	800 lbs. 16% acid phosphate, 100 lbs. sulphate of potash	779	100.59
8	Check. No fertilizer	591	56.26
9	625 lbs. dried blood, 800 lbs. 16% acid phosphate, 100 lbs. sulphate of potash	941	144.57
10	625 lbs. dried blood, 800 lbs. 16% acid phosphate, 100 lbs. muriate of potash	926	150.47
11	500 lbs. 3-8-3 fertilizer	727	85.62
12	1,000 lbs. 3-8-3 fertilizer	862	116.82
13	1,000 lbs. 2-8-2 fertilizer	777	97.31

comes from sulphate of potash or from muriate of potash. Comparison was made between 3-8-3 fertilizer and 2-8-2 fertilizer. It was found that 1,000 pounds per acre of 3-8-3 fertilizer on the average produced $19.51 more to the acre than a similar amount of 2-8-2 fertilizer.

Crop rotation experiments are in progress at this station. The 3-year rotation consists of corn the first year, wheat the second year and clover the third year. Another 3-year rotation is tobacco the first year, wheat the second year and clover the third year. A 4-year rotation which has given satisfaction in this locality is as follows: Corn or tobacco the first year, wheat the second year, mixed grasses the third year and mixed grasses the fourth year. The corn and tobacco receive 1,000 pounds per acre of 3-8-3 commercial fertilizer. Lime is applied at the rate of 1,000 pounds of burnt lime to the acre at the time the grass is seeded. Another satisfactory 4-year rotation in this section is as follows: After the tobacco is harvested the land is seeded to crimson clover and rye; soybeans are grown for hay the second year; and wheat is grown the third year, followed by clover the fourth year.

Variety Tests.—For a number of years farm crops promising for this region have been tested. Variety trials are being conducted with tobacco, corn, oats, wheat, potatoes, rye, cow peas and soybeans. The outstanding varieties of dark tobacco for this region are Lizard Tail, Oronoco and Little Dick. Varieties of corn which do well in this region are Boone County White, Virginia White Dent, Cocke's Prolific, Virginia Ensilage, Gold Standard, Golden Dent, Virginia Yellow Dent and Leaming. Varieties of potatoes adapted to this region are Sir Walter Raleigh, Irish Cobbler and Burbank.

Flax Experiment.—Flax was seeded on land which was in a very good state of fertility of the Cecil sandy loam type on April 14, 1930, 90 pounds of seed being broadcast per acre. Fertilizer was used at the rate of 600 pounds of 4-8-4 commercial fertilizer per acre. The crop was harvested on July 11, 1930, and the dry weight of the crop was 3,600 pounds per acre. After this crop was harvested the same plats were prepared for another crop and reseeded July 11, 1930, using the same rate of seeding and fertilization as in the first crop, but owing to the dry season the second crop did not yield in a satisfactory way.

Other Investigations.—The superintendent of this station carries on experiments in orchard management in several orchards near the station, and he also looks after pasture investigations in the northern end of the county. These lines of work are reported under the departments of horticulture and agronomy, respectively.

James City County Station

The experiments are conducted on a farm about 4½ miles from Williamsburg. The work of this station is confined principally to the experiments with forage crops.

One of the more important experiments deals with the fertilizer requirements for the economical production of alfalfa. This work shows that it is impossible to grow alfalfa successfully in this section without heavy applications of fertilizer. It would appear from results so far obtained that the minimum requirement for good stands of alfalfa in this section is 40 pounds of nitrogen, 40 pounds of potash and 120 pounds of phosphoric acid to the acre. This represents an application of 1,000 pounds of a 4-12-4 fertilizer to the acre. Larger applications up to 1,500 pounds of a similar fertilizer give economical returns. Best stands of alfalfa are obtained where manure is used to furnish nitrogen and potash and is supplemented by phosphoric acid. An application of 10 tons of manure and 500 pounds of 16 per cent superphosphate to the acre usually insures good stands and excellent production. Alfalfa also requires lime for successful growth and at least one ton of ground limestone or its equivalent in other forms of lime should be applied to each acre in addition to the fertilizer before seeding.

Variety and strain tests running over a five-year period show that common American grown alfalfa from Kansas and Utah seed-growing sections give best results. The hardy varieties of alfalfa such as Grimm and Canadian Variegated have done well but have not been superior to the other kinds.

A test of rates of liming at this station shows that optimum results are obtained with alfalfa, red clover and sweet clover where ground limestone is applied at the rate of one ton to the acre every third year. Corn, soybeans, wheat and oats give optimum results where 1,200 to 1,800 pounds of limestone is applied every third year. Rye has shown no response to liming and potato yields have been reduced where more than 1,000 pounds of limestone is applied to the acre.

In forage crop tests Austrian Winter Pea, Crotalaria and perennial lespedeza are showing up as promising new legumes for the section.

Soybean variety tests show Virginia, Laredo, Lexington and Pine Dell to be outstanding hay varieties, while Haberlandt, Hollybrook, Dixie and Tokyo, in the order mentioned, produce a splendid succession of forage for hog pasture.

Caroline County Station

This station is located near Bowling Green, on Norfolk sandy loam soil. Special attention is given to problems connected with the growing of suncured tobacco. Another important line of investigation at this station is a

study of the fundamental principles of crop rotation, which involves observations on the effects of crops upon other crops which succeed them on the same land, and this study is being made in cooperation with the Office of Tobacco Investigations of the Bureau of Plant Industry of the U. S. Department of Agriculture.

Fertilizers for Sun-Cured Tobacco.—Beginning with the year 1925 an experiment was begun to study the comparative merits of different kinds of fertilizer for producing sun-cured tobacco. Nitrogen from organic and inorganic sources was tested and high analysis fertilizer was compared with low analysis fertilizer. Three series of plats, each containing 20 plats, situated on uniform land are being used in the 3-year rotation of tobacco, wheat and red clover. At least two rotations of these crops are necessary before the results will be significant.

Variety Tests of Sun-Cured Tobacco.—Nine varieties of tobacco have been tested on one-tenth-acre plats for several years. An annual application of 1,000 pounds of 3-8-3 fertilizer is given. The 3-year average yield of leaf tobacco, calculated on the basis of an acre, is shown in Table 24, covering the years 1925 to 1927, inclusive.

Table 24.—Tobacco varieties at Bowling Green

	3-year average yield
	Pounds
Little Oronoco	785
Green's Wildfire Resistant Oronoco	896
Narrow Leaf Oronoco	789
White Stem Oronoco	819
Lizard Tail Oronoco	987
Hester	849
Kentucky Pryor	993
Gold Leaf	901
Blue Pryor	879

Variety Tests of Other Farm Crops.—Twenty varieties of corn, 16 varieties of wheat, 8 varieties of oats, 12 varieties of potatoes, and 20 varieties of soybeans are being tested from year to year for the purpose of finding out which varieties of these crops are best suited to this section of Virginia.

Plant Nutrition and Crop Relations Investigations.—These investigations are in cooperation with the U. S. Department of Agriculture. The studies include the effects of certain crops upon others which follow them in rotation; the efficiency of legumes as sources of nitrogen for other crops and the effects of fertilizer on plant growth. The results of the experiments indicate that small grains and grasses give better results when following potatoes or tobacco than when following corn or other small grains similarly fertilized; that tobacco yields may be maintained at least over a period of twelve years, as well under continuous cropping as under rotations if liberal amounts of plant

food are applied in the form of commercial fertilizer; and that vetch, cowpeas, soybeans and crimson clover when well inoculated gather ample nitrogen from the air to supply all of the needs for nitrogen of tobacco and corn crops, which follow them in rotation. Vetch has proved somewhat better than other legumes as a nitrogen gatherer but after four or five years of this crop, wire worms increased so rapidly in the plat that it is difficult to obtain stands of corn and tobacco. This project will be discontinued at the end of the present season and the results reported in a publication as soon as practicable.

Pittsylvania County Station

The Pittsylvania station is situated near Chatham, on Cecil fine sandy loam soil, and special attention is given to problems connected with the growing of bright flue-cured tobacco and to the crops commonly grown on bright tobacco farms.

Fertilizers for Bright Tobacco.—An extensive test was made for the purpose of comparing the effects of nitrogen, phosphorus and potassium derived from different fertilizer sources upon the yield and selling price of bright flue-cured tobacco. The object was to obtain more information which would serve as a basis for compounding formulas for fertilizer to be used on bright tobacco. The tests were made on one-twentieth-acre plats. Fertilizer was applied at the rate of 1,000 pounds of 3-8-3 goods per acre except the check plat. For example, nitrogen check plats received no nitrogen, but they were supplied phosphorus and potassium as in the case of plats receiving complete fertilizer. The results of this study were published in Technical Bulletin No. 35, issued in January, 1929. Important conclusions came from this experiment. Nitrogen from inorganic sources, when used alone was more efficient than nitrogen from organic sources alone. A combination of three parts of nitrogen from high grade inorganic sources and one part from high grade organic sources gave best results. Superphosphate is a satisfactory source of phosphorus for bright tobacco. Potash from sources which carry a small amount of chlorine improve the yield and selling price of bright tobacco. A satisfactory fertilizer for bright tobacco may be made by obtaining three-fourths of the nitrogen from high grade inorganic carriers and one-fourth from high grade organic carriers. The phosphorus may be obtained from superphosphate, and the potash, 2 per cent from muriate of potash and the remainder from high grade potash salts which contain no chlorine.

Investigations were made comparing different quantities of 3-8-3 fertilizer per acre, which showed that heavy applications were more profitable up to 1,200 pounds per acre. Quantities greater than 1,200 pounds per acre did not pay. Applications of 2-8-2 fertilizer did not give results so satisfactory as the application of 3-8-3 fertilizer.

Satisfactory results were secured when one-half of the fertilizer was applied in the drill and the other half as a side dressing at the time of the first cultivation of the tobacco plants.

Priming vs. Cutting.—A test extending over three years was made to compare priming and cutting as methods of harvesting tobacco. Priming gave a slightly better return in cases where the tobacco was topped low and at the same height. Where primed tobacco was topped high returns per acre have been decidedly better than where the tobacco was topped low and harvested by cutting.

Crop Rotations.—Experiments are being conducted on types of rotations suitable for land on which bright tobacco is grown, and also rotations for land on which other crops are grown. It is not feasible to include leguminous crops in rotations which include bright tobacco.

Variety Tests.—Variety tests are conducted from year to year on potatoes, cow peas, soybeans, oats, corn, wheat and rye to determine the best varieties for this section of Virginia.

Growing Flax.—A plat of flax was grown in 1929. The seed was sown at the rate of 90 pounds per acre, and an application of 400 pounds of 3-8-3 fertilizer was given the land. The first cutting yielded 1,240 pounds per acre, but the second crop failed, on account of dry weather.

Drought Spot of Tobacco.—A study is being made of the effects of different kinds and amounts of fertilizer on drought spot of tobacco. The dry season of 1930 afforded a splendid opportunity for a critical test of fertilizers on this malady. It was found that spotting was severe with normal applications of 3-8-3 fertilizer, but was no more severe under heavy applications than under lighter applications of fertilizer. It appears that the amount of chlorine present in the fertilizer has a decided effect on the amount and severity of drought spot.

Nansemond County Station

This station is located near Holland, on Onslow sandy loam soil. Special attention is given to problems connected with the production of cotton and peanuts.

Experiments with Cotton.—The growing of cotton in southeastern Virginia is being gradually curtailed, chiefly because of the low price of cotton and the injury caused by boll weevil, which recently appeared in this section. The effects of applications of lime and the effects of applications of different kinds and quantities of fertilizer to cotton are being studied from year to year. A study is being made of the proper percentages of organic and inorganic nitrogen to use in cotton fertilizer. These studies indicate that about 35 per cent of the nitrogen should be obtained from organic carriers and 65 per cent from inorganic carriers for best results.

Experiments with Peanuts.—Experiments are being made on the effects of different amounts and kinds of lime on peanut production. It has been found that where sufficient lime is used, gypsum or land plaster is not required, and where this material is used in large quantities actual damage results. A strain of the Jumbo variety of peanuts is giving promising results.

Soybeans.—Extensive variety tests of soybeans are being made from year to year, and the results have proved interesting to farmers in this section of Virginia.

Augusta County Station

The Augusta County station is located near Fishersville, on the DeKalb type of soil, and this soil type prevails over a large area in the valley region of Virginia. A number of experiments are in progress dealing with farming problems in this section of the state.

Rates of Applying Lime.—This experiment has been running over a period of seven years. The soil is limed at different rates beginning with 600 pounds per acre, and running up to a maximum of 4,800 pounds per acre. Corn, wheat, sweet clover, soybeans, rye, alsike clover, potatoes, barley and red clover are grown under these different rates of liming. The results for the past seven years show that light applications of lime are just as satisfactory as heavy applications, and there is no advantage in applying more than 1,800 pounds of lime per acre to the crops included in this study.

Fertilizer Experiments.—Fertilizer experiments have been in progress for a period of seven years. Different kinds of fertilizer are used, different quantities, and fertilizers derived from different sources are being tested. The fertilizer applications are used both on land which has been limed and land which has not been limed. As a general rule fertilizers and lime together produced the most satisfactory results. In these tests applications of phosphate have paid highest returns for each dollar invested. However, potash pays for its use in yield and improved quality. Nitrogen pays well on plats which do not grow legumes, but may be maintained in sufficient quantities by the proper use of legumes in the rotations.

Crop Rotations.—Several types of crop rotations are being tested at this station. A short rotation of corn, wheat and clover seems to fit the needs of the locality somewhat better than longer rotations.

Variety Tests.—Nine varieties of wheat are being grown from year to year to test their comparative merits in this section of the state. Also, several varieties of oats are being tested from year to year, and a number of varieties of soybeans.

Flax Experiment.—In 1929 two crops of flax were obtained from the same land. The first cutting yielded three tons per acre and the second cutting yielded one ton per acre.

Charlotte County Station

This station is located near Charlotte Court House, on Cecil sandy loam soil. Special attention is given to the investigation of problems connected with dark tobacco growing, and other crops commonly grown on dark tobacco farms.

Corn Experiments.—Variety tests are being made on eleven varieties of corn, including both white and yellow varieties, and the leading varieties for this section of Virginia are Boone County White, Virginia White Dent and Reid's Yellow Dent.

Fertilizers for Grass and Grain Rotation.—The purpose of this experiment is to determine a suitable fertilizer for a rotation of grass and grain in this section. Four 1-acre plats are being used and a 4-acre rotation is followed, including corn, wheat, and grass for two years. Each acre is divided lengthwise into sub-plats and one-half is limed at the rate of two tons of ground limestone to the acre every fourth year. The grass mixture used is sapling clover, timothy and red top.

Wheat.—Eight varieties of wheat are being tested to determine their adaptation to this section.

Other Variety Tests.—Tests are being run on five varieties of winter oats, seven varieties of potatoes, fifteen varieties of soybeans and ten varieties of cow peas.

Tobacco Fertilizer.—A study is being made of the relative value of nitrogen from different carriers in the production of dark tobacco. Twenty-two plats are used in this experiment, which has been under way for several years.

Washington County Station

Our lease on land near Martinsville ran out at the close of 1929, and since it was not practicable to lease suitable land nearby for continuing the work at the Henry County station is was decided to discontinue the work at that place and to move the experiment station to Washington County, near Glade Spring. Work at the Washington County station was begun April 1, 1930. The principal work at this new station will be investigations of pasture problems and experiments on feed crops commonly grown in Southwest Virginia. Several projects have been taken up, including the following: (1) A study of the effects of fertilizer on the carrying capacity and vegetation of old pasture sods. (2) A comparison of the value and adaptability of various pasture plants. (3) Rotation studies for the production of grain and forage. (4) Fertilizer tests on feed crops. (5) Variety tests of grain and forage crops.

METEOROLOGICAL RECORDS

Dean H. L. Price has had charge of the keeping of the weather records for about 33 years, serving as cooperative observer for the Weather Bureau. The weather records are needed particularly in connection with the field experiments on farm crops and orchards, and with the studies of plant diseases and insect pests. Weather records are very necessary in these experiments and studies. Tables 25 to 30 give the weather records at Blacksburg for the years 1928 to 1930, inclusive. The temperature readings are recorded in degrees Fahrenheit.

Table 25.—Reading of maximum and minimum thermometers, 1928

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	48	3	43	20	53	30	59	27	66	45	74	39	80	55	87	54	69	56	55	48	58	25	51	40
2	14	-3	43	18	40	20	65	31	74	38	76	60	81	55	85	60	58	54	61	48	62	35	49	24
3	16	3	56	19	49	27	71	39	81	36	70	48	86	55	90	63	78	56	73	48	67	50	59	29
4	27	3	61	25	46	21	75	44	88	43	73	55	87	57	85	65	78	53	74	54	61	43	62	28
5	36	11	52	39	42	27	72	49	82	48	80	58	81	63	90	62	67	54	78	56	65	26	51	34
6	53	18	41	29	47	15	73	49	68	43	70	57	83	64	89	63	62	51	69	52	60	31	48	19
7	59	29	35	26	60	24	66	52	47	41	62	51	87	57	87	63	74	54	74	45	59	34	41	15
8	51	31	59	33	61	26	64	35	56	42	73	42	88	63	90	58	78	55	73	42	58	44	37	20
9	45	34	53	34	61	40	53	32	68	41	83	52	84	62	86	63	79	46	80	48	51	34	35	19
10	51	30	37	27	58	28	38	32	79	35	79	52	81	65	82	55	81	46	74	46	41	30	44	18
11	60	32	40	27	49	31	38	31	83	46	69	55	86	61	75	65	83	48	79	41	43	32	58	18
12	60	32	47	27	67	35	60	33	74	41	78	57	84	65	80	64	81	58	80	46	50	26	49	20
13	60	33	37	22	69	35	64	28	69	31	82	57	83	62	77	59	83	53	79	41	52	32	57	29
14	66	36	40	29	63	45	64	42	68	39	82	61	77	63	79	63	86	56	81	56	61	21	51	43
15	64	46	44	34	55	34	61	30	73	43	79	50	77	54	77	64	85	63	75	45	71	31	52	38
16	60	41	40	31	47	33	53	20	79	43	75	49	81	58	72	63	82	60	72	59	66	36	54	31
17	58	35	50	29	41	31	48	22	79	55	78	50	84	67	72	63	78	61	70	62	68	35	56	40
18	56	50	41	17	32	25	61	30	69	56	77	60	88	67	74	63	74	55	72	62	71	59	54	29
19	51	41	36	12	33	23	70	46	76	55	84	64	88	61	80	64	55	48	71	45	65	50	49	17
20	49	26	42	22	40	18	68	46	75	56	85	60	89	61	83	55	59	46	59	41	52	31	40	27
21	28	10	39	16	41	27	61	40	78	50	82	60	91	66	88	58	77	46	60	30	41	26	35	23
22	40	12	39	19	63	30	69	41	77	55	82	61	88	65	81	61	74	51	58	37	42	29	36	13
23	49	21	57	31	69	40	65	52	79	57	78	61	84	64	80	59	70	50	60	54	35	27	42	12
24	48	28	50	33	69	33	63	41	68	42	79	58	86	61	81	64	61	37	58	40	54	22	44	14
25	45	29	36	22	68	43	60	38	68	43	75	56	85	61	78	61	65	33	55	34	48	21	50	16
26	48	23	36	17	76	40	59	27	67	43	77	51	86	56	79	66	59	33	51	30	30	17	49	18
27	39	18	45	17	64	33	55	35	64	42	74	51	84	64	83	66	60	38	57	25	42	25	43	24
28	33	7	51	25	56	26	38	30	74	41	78	49	83	63	85	60	68	41	52	44	52	30	53	31
29	18	4	57	25	78	33	63	36	71	40	74	63	79	56	87	61	68	49	51	29	55	38	52	35
30	29	17	-----	-----	67	46	71	39	68	40	72	60	75	59	86	66	65	55	45	20	52	40	44	24
31	30	21	-----	-----	47	27	-----	-----	70	47	-----	-----	77	59	74	65	-----	-----	51	30	-----	-----	43	22
Average	44.5	23.1	45.1	25.0	55.2	30.5	60.9	36.6	72.2	44.4	76.7	54.9	83.6	60.9	81.8	61.8	71.9	50.0	66.0	43.8	54.4	32.7	47.8	24.8

Table 26.—Reading of maximum and minimum thermometers, 1929

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	47	34	31	18	51	33	73	50	79	49	86	54	80	60	86	58	85	43	71	51	78	55	39	4
2	41	22	28	5	46	30	66	33	76	53	67	48	78	52	87	63	89	55	52	47	78	55	34	20
3	37	11	38	5	52	20	73	29	69	36	64	47	74	50	80	63	89	44	59	43	69	57	31	14
4	47	18	40	14	51	29	74	41	78	34	78	37	84	42	79	62	84	56	59	38	60	44	29	11
5	39	24	34	21	52	32	81	49	67	46	75	42	84	58	77	45	88	55	56	41	50	33	53	19
6	35	23	35	24	58	28	84	56	67	40	79	45	85	51	80	54	88	57	72	49	59	21	57	24
7	33	18	37	31	52	35	83	49	64	52	80	52	87	51	80	61	91	62	70	56	59	27	57	29
8	33	8	52	23	47	18	83	48	69	37	76	52	86	60	73	63	88	62	65	36	54	34	53	37
9	47	16	50	26	47	27	82	47	66	45	63	56	88	60	81	62	84	63	63	29	58	30	60	23
10	52	34	43	23	47	10	78	50	68	43	76	49	87	59	86	57	83	62	59	38	58	24	60	25
11	44	28	32	21	57	18	73	41	71	40	78	44	82	63	80	62	75	45	61	34	65	39	62	32
12	36	17	33	16	60	28	63	40	82	44	85	50	72	63	86	62	76	42	68	31	60	44	52	32
13	39	23	38	14	60	50	73	34	80	50	84	59	80	63	87	58	79	63	68	41	58	51	62	31
14	35	6	44	14	68	55	73	43	74	50	79	59	83	60	87	59	80	58	66	40	68	50	62	47
15	46	15	41	23	65	56	60	42	78	57	79	59	74	62	77	55	74	44	62	32	62	55	65	47
16	41	29	37	29	60	41	46	36	74	58	82	52	76	53	81	42	77	49	70	33	56	38	66	46
17	43	30	51	24	42	32	43	37	64	35	85	54	77	59	86	52	75	60	66	44	60	47	52	40
18	64	34	56	21	60	24	58	34	76	46	85	58	84	57	86	59	69	44	67	33	57	39	52	46
19	63	46	62	27	60	28	68	32	75	53	88	60	82	62	86	57	68	34	75	31	43	33	52	29
20	51	31	55	21	56	33	76	35	60	47	84	59	75	56	78	57	63	33	77	35	43	26	29	12
21	49	25	38	16	68	34	74	51	61	45	85	58	74	43	80	49	64	39	69	53	39	25	28	11
22	43	31	37	24	72	50	69	41	66	34	86	59	82	51	81	53	61	46	68	48	31	20	26	20
23	51	32	35	13	66	55	64	27	71	36	81	63	83	55	79	60	70	51	60	37	31	22	31	21
24	46	30	52	13	83	52	71	33	77	44	82	65	85	56	78	63	68	56	52	34	38	26	27	13
25	51	29	45	23	84	46	71	51	78	49	80	62	83	63	74	60	70	59	44	35	35	27	30	15
26	46	17	59	38	77	50	65	50	78	53	75	62	85	62	80	46	73	61	65	30	53	33	45	18
27	34	16	53	40	65	37	71	35	78	51	80	61	80	63	83	50	81	53	69	36	53	38	47	17
28	35	25	51	39	64	45	67	49	84	51	80	53	90	56	80	55	85	49	64	37	46	32	51	34
29	31	15			63	28	63	41	82	59	74	60	89	60	76	55	86	52	55	39	34	19	43	27
30	30	14			59	38	71	33	80	56	77	48	86	61	74	50	82	52	47	41	19	0	51	24
31	31	14			69	34			84	58			86	61	80	40			64	45			62	32
Average	42.6	23.1	43.1	21.6	60.0	35.4	69.7	41.2	73.3	46.8	79.1	54.2	82.0	57.2	80.9	55.9	78.2	51.6	63.3	39.3	52.3	34.8	47.4	25.8

Table 27.—Reading of maximum and minimum thermometers, 1930

Date	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	64	33	41	0	58	32	64	23	81	49	78	34	86	61	88	52	95	56	70	34	42	29	48	37
2	59	34	41	26	54	20	60	40	82	46	83	38	84	57	92	57	96	57	71	30	50	16	43	14
3	53	34	54	31	37	10	55	45	76	50	85	41	82	58	95	56	92	61	76	37	46	22	51	16
4	39	20	49	32	35	17	64	37	82	39	88	44	87	57	98	66	88	65	74	36	44	41	53	21
5	43	15	45	35	55	15	66	32	85	44	86	48	94	57	98	65	87	64	75	37	49	41	41	31
6	50	18	53	30	57	20	60	45	82	59	78	64	94	62	91	70	91	58	79	35	48	29	41	37
7	59	37	58	24	58	41	58	38	86	49	76	56	93	65	95	65	80	58	74	39	45	16	44	36
8	62	39	55	27	47	34	50	33	86	57	72	49	94	51	93	66	85	61	68	47	59	16	40	30
9	70	37	50	19	49	32	61	31	82	56	68	51	92	57	98	63	80	62	66	54	64	20	50	28
10	56	37	48	27	61	27	77	29	83	49	70	47	92	62	91	67	73	62	78	53	64	29	60	35
11	41	33	49	28	55	36	84	47	78	56	75	44	94	55	81	51	77	56	81	42	56	37	54	40
12	51	30	56	23	45	29	84	47	74	56	75	53	94	66	81	42	83	62	75	42	52	44	48	34
13	60	38	49	34	69	30	80	50	78	55	79	53	88	59	83	43	82	65	71	41	55	47	44	25
14	64	41	41	28	59	35	76	46	76	56	79	61	88	62	79	51	85	60	74	58	56	50	40	30
15	58	45	38	23	52	31	72	42	70	47	81	59	78	53	85	61	91	56	73	57	54	47	36	31
16	46	24	32	7	69	25	71	46	73	46	83	57	76	59	87	53	85	65	79	47	59	51	31	12
17	30	17	39	20	66	35	62	43	80	50	80	62	77	60	89	60	80	60	73	49	63	55	25	15
18	29	18	60	20	62	44	66	44	74	50	83	56	90	61	77	65	78	54	68	31	70	49	34	7
19	35	5	64	23	54	34	62	50	78	61	85	52	93	60	79	55	72	55	56	32	63	48	34	12
20	37	8	68	27	54	25	68	28	75	58	80	56	96	63	79	56	72	58	52	30	54	45	35	20
21	38	27	70	26	56	32	67	45	76	42	84	60	96	63	75	61	82	62	49	27	63	43	37	−2
22	38	32	70	26	49	27	63	46	81	43	86	56	95	67	71	56	87	57	53	16	61	49	30	−1
23	33	18	65	35	57	18	58	32	83	48	90	58	90	65	71	58	90	60	47	27	55	32	28	5
24	35	9	72	37	56	31	52	29	78	52	96	58	89	64	77	50	90	56	44	40	49	26	26	7
25	34	18	78	47	54	40	57	28	66	40	92	62	95	55	84	49	87	60	47	35	40	25	34	−6
26	35	18	73	49	48	23	57	29	68	35	94	56	97	58	83	49	86	59	61	21	35	23	37	24
27	37	24	56	37	45	30	70	26	74	43	80	62	89	66	82	48	80	51	69	25	28	7	38	28
28	48	33	55	32	54	26	77	41	79	44	82	48	99	66	87	48	75	43	64	43	24	14	32	20
29	38	22	-----	-----	56	26	70	50	69	53	90	54	98	65	91	52	71	48	57	49	40	11	33	27
30	32	17	-----	-----	51	28	81	46	65	47	90	56	90	57	91	53	73	43	53	33	49	26	32	20
31	31	−1	-----	-----	53	25	-----	-----	65	36	-----	-----	87	55	95	55	-----	-----	45	35	-----	-----	32	3
Average	45.1	25.2	54.6	27.4	53.9	28.2	66.4	38.9	76.9	48.9	82.3	53.2	89.9	60.2	86.0	56.2	83.1	57.8	65.2	38.1	51.1	32.8	39.1	20.5

Table 28.—Showing meteorological data January 1, 1928, to December 31, 1928

	Mean temp. for month	Mean max. temp. for month	Mean min. temp. for month	Average daily range	Highest temperature	Lowest temperature	Monthly range	Precipitation in inches	Snow in inches	Prevailing winds	Number clear days	No. partly clear days	Number cloudy days
January	33.8	44.5	23.1	21.5	66	-3	69	2.02	0.75	W	19	0	12
February	35.0	45.1	25.0	20.1	61	12	49	1.74	0.50	W	12	4	13
March	42.8	55.2	30.5	24.7	78	18	60	2.82	5.12	N W	17	3	11
April	48.7	60.9	36.6	24.3	75	20	55	3.28	8.70	S W	7	7	16
May	58.3	72.2	44.4	27.8	83	31	52	2.50	....	N W	14	2	15
June	65.8	76.7	54.9	21.8	85	39	46	4.84	....	W	9	3	18
July	72.2	83.6	60.9	22.7	91	54	37	2.20	....	N W	25	3	3
August	71.8	81.8	61.8	20.0	90	54	36	3.41	....	N W	16	3	12
September	60.9	71.9	50.0	21.9	86	33	53	6.62	....	N W	17	2	11
October	54.9	66.0	43.8	22.2	81	20	61	1.84	....	S E	12	7	12
November	43.5	54.4	32.7	21.7	71	17	54	0.94	1.60	N W	12	5	13
December	36.3	47.8	24.8	23.0	62	12	50	1.03	0.90	N W	18	1	12

Table 29.—Showing meteorological data January 1, 1929, to December 31, 1929

January	32.8	42.6	23.1	19.5	65	6	59	2.43	1.90	N W	15	3	13
February	32.3	43.1	21.6	21.5	62	5	57	5.04	26.90	N W	13	2	13
March	47.7	60.0	35.4	24.7	84	10	74	4.38	Trace	S W	15	3	13
April	55.4	69.7	41.2	28.5	84	27	57	3.40	Trace	S W	20	2	8
May	60.0	73.3	46.8	26.5	84	34	50	3.06	Trace	S W	12	8	11
June	66.7	79.1	54.2	24.9	88	37	51	6.55	....	N W	20	4	6
July	69.6	82.0	57.2	24.8	90	42	48	4.28	....	S W	23	4	4
August	68.4	80.9	55.9	25.0	87	40	47	1.94	....	N W	23	5	3
September	64.9	78.2	51.6	26.5	91	33	58	1.58	....	S E	16	5	9
October	51.3	63.3	39.3	24.1	77	29	48	3.14	....	N W	18	1	12
November	43.5	52.3	34.8	17.5	78	0	78	3.48	3.80	N W	9	3	18
December	36.6	47.4	25.8	21.5	66	4	62	2.37	10.30	N W	12	2	17

Table 30.—Showing meteorological data January 1, 1930, to December 31, 1930

January	35.1	45.1	25.2	20.0	70	-1	71	1.78	12.20	N W	10	3	18
February	41.0	54.6	27.4	27.2	78	0	78	1.25	0.30	S W	14	7	7
March	41.0	53.9	28.2	25.7	69	10	59	1.02	0.70	N W	16	2	13
April	52.6	66.4	38.9	27.5	84	23	61	1.54	....	N W	18	4	8
May	62.9	76.9	48.9	28.0	86	35	51	1.77	....	N W	16	7	8
June	67.7	82.3	53.2	26.9	96	34	62	1.37	....	N W	19	4	7
July	75.0	89.9	60.2	29.7	99	51	48	0.93	....	N W	22	3	6
August	71.1	86.0	56.2	29.8	98	42	56	1.03	....	N W	26	1	4
September	70.4	83.1	57.8	25.3	96	43	53	2.19	....	N W	21	2	7
October	51.6	65.2	38.1	27.1	81	16	65	1.60	Trace	N W	17	3	11
November	41.9	51.1	32.8	18.3	70	7	63	2.96	0.80	S E	17	1	12
December	29.8	39.1	20.5	18.5	60	-6	66	2.46	18.00	N W	12	2	17